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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 550
Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C. ▼ August 9, 1917

CONTROL OF THE GRAPE-BERRY MOTH IN THE ERIE-CHAUTAUQUA GRAPE BELT

By

DWIGHT ISELY, Scientific Assistant, Deciduous Fruit Insect Investigations

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INTRODUCTION.

Of the grape pests of the Erie-Chautauqua grape belt none is more baffling to control or more discouraging to the vineyardist than the grape-berry moth (*Polychrosis viteana* Clem.) (Pl. I). Owing to its direct attack upon the fruit, its ravages are felt at once wherever it is present in destructive numbers. It is very erratic in its occurrence, both locally and seasonally. In some years it may be practically absent from the majority of the vineyards of the belt, whereas in other years it is often not only the pest of first importance, but its ravages exceed those of all other pests combined.

To establish means of control for this pest experiments were conducted at North East, Pa., during the seasons of 1914, 1915, and 1916.[1]

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[1] This investigation was conducted under the direction of Dr. A. L. Quaintance, Entomologist in Charge of Deciduous Fruit Insect Investigations of the Bureau of Entomology. At the outset the work was greatly facilitated by the temporary association of Mr. Fred Johnson, formerly of this bureau, who placed at the writer's service his extended knowledge of grape insects and conditions in the Erie-Chautauqua grape region. The writer was assisted during the seasons of 1914 and 1915 by Mr. E. R. Selkregg and in 1916 by Mr. James K. Primm. Parallel with the experiments for direct control of the grape-berry moth, a study of its parasites was made by Mr. R. A. Cushman, from whom valuable cooperation was received. To these gentlemen and the cooperating vineyardists the writer wishes to express his appreciation for numerous courtesies.

NOTE.—This bulletin will be of interest to grape raisers in New York, Pennsylvania, Michigan, and Ohio.

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The results of these experiments constitute the chief subject matter of this bulletin. Only such biological data as are necessary as a basis for the remedial work are included. Various control measures which have been employed are given place in the earlier part of the paper, but chief attention is devoted to spraying, which has proved to be the most effective means of control.

FOOD PLANT.

The grape, as far as is known, is the only food plant of the larva of the grape-berry moth, and since the larvæ usually feed upon the grape berry, it is from this habit that its common name is derived. Before the berries are developed, the few early larvæ feed in the blossom clusters. In confinement larvæ may feed sparingly on grape leaves and stems.

DISTRIBUTION.

The distribution of the grape-berry moth extends throughout the United States from east of the Great Plains to the Atlantic, and from the southern portion of the Canadian Province of Ontario to the Gulf of Mexico. The States from which it has been recorded in publications and in unpublished files of the Bureau of Entomology are as follows: Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, Ohio, Indiana, Illinois, Wisconsin, Michigan, Missouri, Iowa, Nebraska, Kansas, Virginia, South Carolina, Florida, Alabama, Kentucky, Louisiana, Arkansas, and Texas. Most frequent complaints of its destructiveness have come to the Bureau of Entomology from New York, Pennsylvania, New Jersey, and Ohio.

ECONOMIC STATUS.

The grape-berry moth is a major grape pest in the eastern United States, on the whole probably being exceeded in destructiveness by the grape rootworm (*Fidia viticida* Walsh) and the grape leaf-hopper (*Typhlocyba comes* Say). However, its exact status as a pest is uncertain. In some grape-growing regions, within the limits of distribution, its presence is ignored or even unknown to the growers. It is exceedingly erratic and local in occurrence, and the damage which it inflicts varies greatly from year to year. The history of the grape-berry moth in the Erie-Chautauqua grape belt is an example of this variation. In the western part of the grape belt, in Pennsylvania, during the season of 1916 this insect was by far the most destructive grape pest; in the eastern part of the grape belt, in New York, it was not generally regarded seriously, yet Slingerland in 1904 reported it as very destructive throughout all of this region, particularly near Brocton, N. Y., where in one vineyard as high as 90 per cent of the fruit was ruined.

The extensive grape regions of Michigan have been the source of very few complaints of loss due to the grape-berry moth. In the summer of 1915 the writer visited many vineyards in the vicinity of Benton Harbor, St. Joseph, Paw Paw, and Lawton, Mich., and found the berry moth present in practically all of them, although usually in small numbers. Its destructiveness in this region is obscured by the greater and more consistent injury by the black-rot fungus, and probably injury by the grape-berry moth is often attributed to the black-rot fungus. In contrast to this, in the Ohio grape regions it has been consistently destructive and the leading grape pest for years. Even in a region where the grape-berry moth is a recognized pest it is by no means consistent in occurrence, and may be erratic and local even within a vineyard. In the vicinity of North East, Pa., in the western part of the Erie-Chautauqua grape belt, in most seasons fully half of the vineyards are practically free from it. In others the outside rows, ends of rows, or irregular spots are heavily infested, while the rest is practically free. Yet there are many vineyards that annually sustain the loss of from one-fourth to one-half the crop.

DESTRUCTIVENESS WITHIN A VINEYARD.

The destructiveness of the grape-berry moth is underestimated greatly even in vineyards where it is recognized as the chief pest, and where the infestation is light it is usually ignored. This is due to the fact that "wormy" grapes, unless very heavily infested, will bring a price comparatively near the standard price, seldom with a reduction of more than 10 per cent. Even when the infestation approaches total, the price may be much nearer to the standard for grapes than the price for cider apples is to the standard price for apples. Because of this the vineyardist is apt to consider the reduction in price as the chief loss and largely disregard what may be a greater charge against the berry moth—the reduction in weight.

The berries infested by first-brood larvæ (see Pl. II, fig. 1) are totally lost, although if they are destroyed very early in the season this loss may be partially offset by increased weight in the rest of the cluster. Those infested by the second brood (see Pl. II, fig. 2), which the larvæ have left or in which the larvæ are well grown, lose weight rapidly; by the end of the season they are little more than dry shells and have but a fraction of their former weight (Pl. III, fig. 1). This loss varies greatly, depending upon the time when the berries are infested and upon the time of harvest.

"Wormy" grapes are of course largely excluded from the market for basket grapes, for unfermented juice, and for some wines, unless all of the "wormy" berries are trimmed out. This exclusion from certain markets may in certain years represent a considerable loss.

If the infested berries are trimmed out of the clusters the loss of their weight is total in addition to the cost of trimming.

While the berry moth is not as generally destructive as the grape rootworm or grape leafhopper, it is capable of inflicting greater losses than either to a single season's crop, and neither of these pests will appear in destructive numbers with such alarming rapidity in a vineyard which has been apparently free from them as will the grape-berry moth. When it is present at all in a vineyard it always causes a loss in weight and is a constant menace to the grape industry in that vicinity.

SUMMARY OF SEASONAL HISTORY AND HABITS.[1]

Before considering control measures, a summary of the seasonal history and habits upon which these measures are based will be given.

There are two broods of the grape-berry moth that must receive economic consideration. The first brood, resulting from the hibernating generation, is comparatively small, owing to high winter mortality of the pupæ. The earliest recorded emergence of moths is May 29 and the latest July 26; however, the bulk of the emergence begins between the 10th and the 25th of June, varying with the season, and usually is ended within 3 weeks. Within 4 to 6 days after emergence the moths (Pl. I, figs. 4, 5) begin depositing eggs, preferably on grape berries. Incubation requires about 6 days. Thus the hatching period of large numbers of larvæ begins from June 20 to July 5, depending upon the season, and continues for about 3 weeks.

The beginning of this period is almost coincident with the falling of the grape blossoms and the setting of the fruit. The larval feeding period averages 23 days, after which the larvæ (Pl. I, fig. 1) spin cocoons in leaves on the vine, and in an average of 13 days emerge as moths. Some pupæ (Pl. I, fig. 3), however, do not transform at this time but remain in the cocoon (Pl. I, fig. 2) until the following spring.

The earliest recorded emergence of summer-brood moths is July 12 and the latest is after the middle of September. A heavy emergence of moths begins in a normal season in the latter part of July, and in backward seasons may continue as late as the earlier part of September. Although the second brood is only a partial one, it is by far the more numerous and destructive. It may escape serious attention from the vineyardists until shortly before harvest, when the well-grown larvæ begin to leave the berries they first attacked and to enter others.

The development of this brood is slower than that of the first. In a normal season the larvæ are cocooning in large numbers by the latter part of September and by the middle of October most of them

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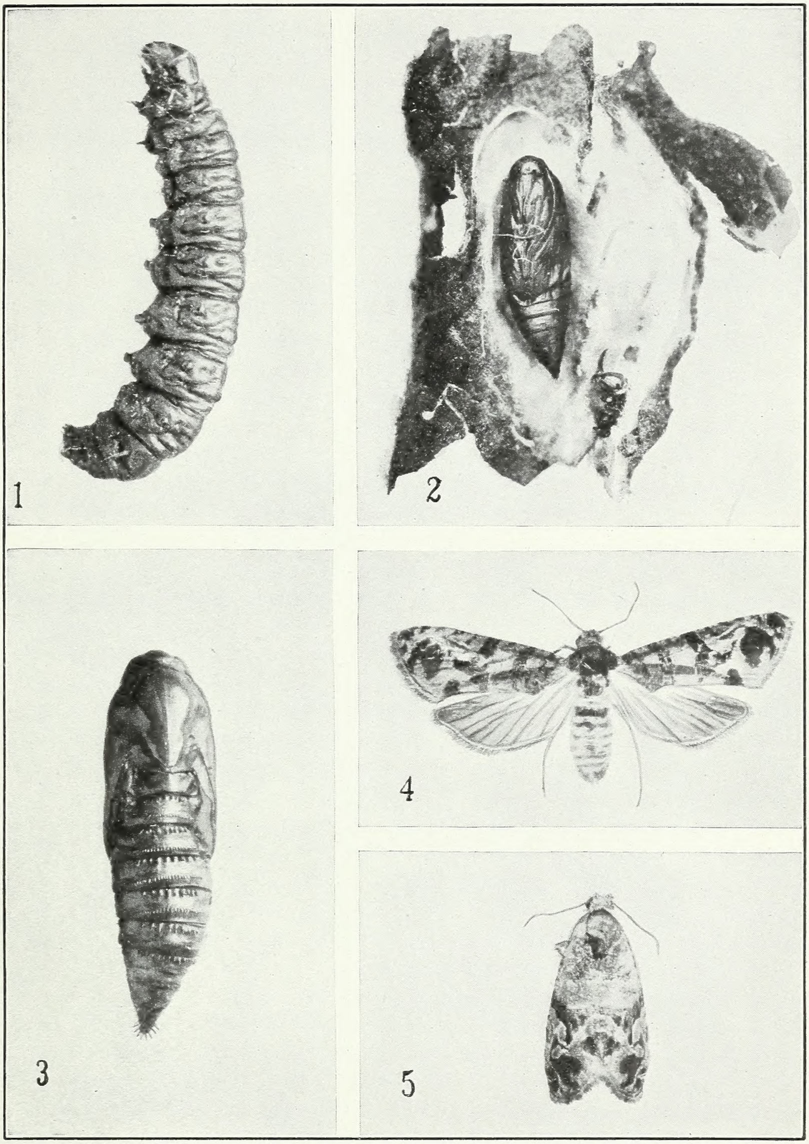
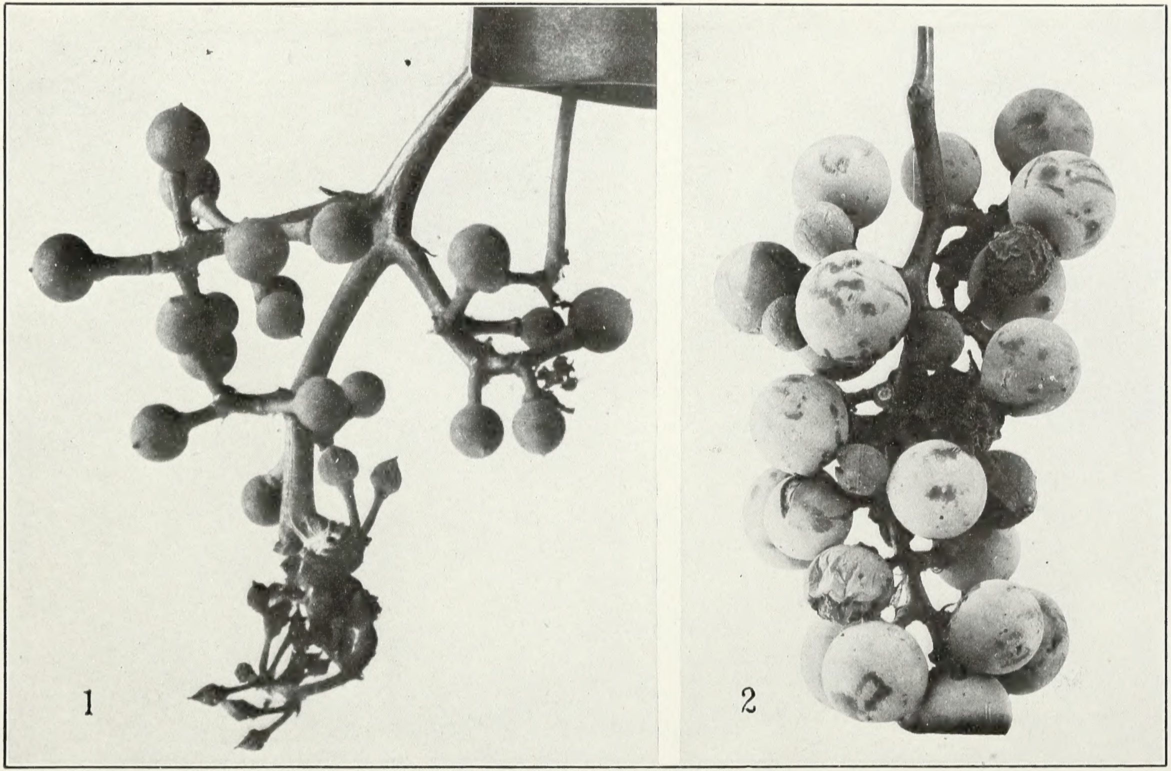
[1] This summary is based on the life-history studies of the grape-berry moth by Johnson and Hammar, and studies by the writer and his associates, the details of which have not yet been published.

PLATE I.



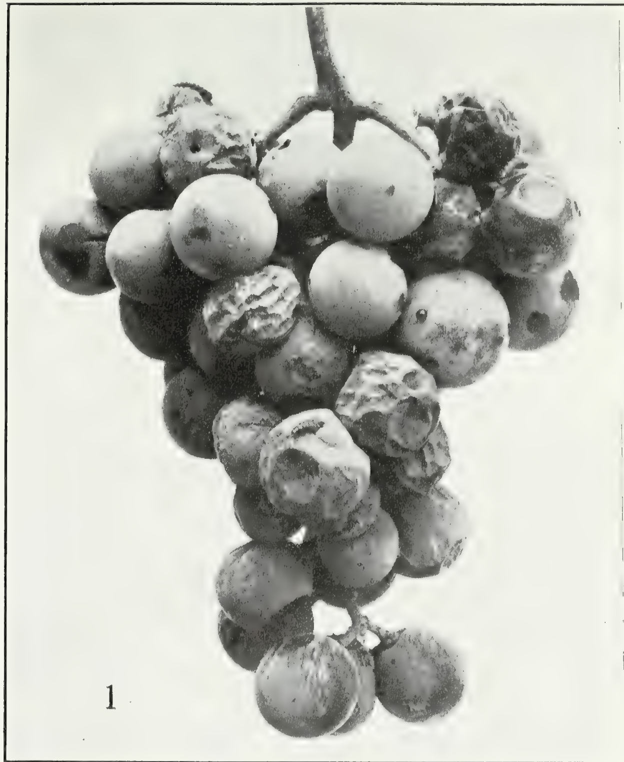
THE GRAPE-BERRY MOTH (POLYCHROSIS VITEANA).

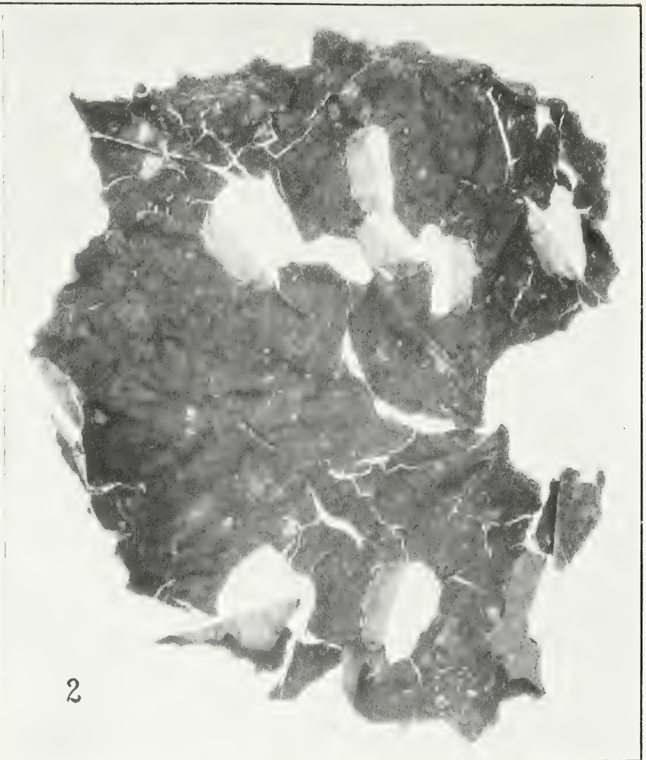
FIG. 1.—Larva. FIG. 2.—Pupa (ventral aspect) in cocoon. FIG. 3.—Pupa (dorsal aspect). FIGS. 4, 5.—Adult. All greatly enlarged. (Original.)



GRAPE CLUSTERS ATTACKED BY FIRST-BROOD GRAPE-BERRY MOTH LARVÆ.

FIG. 1.—Injury by earliest larvæ, showing webbing of cluster. FIG. 2.—Injury by later larvæ, showing undersized, cracked, and shriveled berries which have begun to fall. Note second-brood eggs on surface of berries. (Original.)





DAMAGE BY THE GRAPE-BERRY MOTH.

FIG. 1.—Grape cluster at harvest time, heavily infested with second-brood grape-berry moth larvæ. FIG. 2.—Cocoons in sodden grape leaf under trellis. (Original.)

have left the berries. However, in the very late autumn of 1915 the majority of the larvæ did not leave the berries until after October 25.

Winter is passed in a cocoon, usually spun in a decayed grape leaf under the trellis. (Pl. III, fig. 2.)

FEEDING HABITS OF LARVÆ.

The very few early larvæ which hatch before the grape blossoms fall feed in the blossom cluster. But most of them, coming after the grapes are set, eat at once into the berry, causing the characteristic purple spotting and cracking of grape berries.

The point of entrance may be anywhere on the surface of the grape berry, but before the berries touch, about half of the larvæ enter around the stem attachment. Of 500 infested berries counted on July 14, 1916, about 12 days after setting of grapes, 266 were entered at the stem end and the other 234 from other parts of the grape berry. After the grape berries reach the stage of growth where they begin touching, the point of contact becomes the most common place of entrance.

The early larvæ, which hatch when the grape berries are still small, destroy many more berries than do larvæ which hatch after the grapes are larger.

FLIGHT OF MOTHS.

The distance which moths of this species may fly in large numbers is uncertain, but as a rule the spread of infestation is slow. In one instance serious infestation advanced from a heavily infested vineyard into an adjacent young vineyard not more than 100 or 120 feet distant. In this vineyard there could have been no previous infestation, as it had just come into bearing. Some infested berries were found 350 feet from the older vineyard, but very few. On the other hand, the following season a vineyard about 1,100 feet wide, newly in bearing, was traversed and infested heavily by a single generation. The spreading of infestation probably is much influenced by weather conditions at the time of the flight of moths. While it may be slow ordinarily, no vineyard is immune from rapid infestation in a vicinity where the berry moth is present.

HISTORY OF CONTROL METHODS.

Measures to control the grape-berry moth, since its appearance as an economic pest, have developed gradually from many sources. The first considerable advance toward a solution of the problem, however, was made by the biological and systematic studies of Slingerland (9)[1] and Kearfott (8) in which they definitely determined the limits of the species and the fact that the grape was its only food plant; and by Slingerland's field experiments, which were the first in which spraying was attempted as a primary means of reducing its destructiveness.

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[1] Reference is made by number to "Literature cited," p. 42.

Gathering and burning grape leaves in the fall, to destroy the hibernating insects, was recommended first by Walsh and Riley (1). This recommendation remained in good standing until it was questioned by Webster (5), because he was unable to rear any moths from collected leaves, and since that time it has appeared less frequently. Slingerland recognized the general futility of this practice and termed it "the least effective measure."

The bagging of clusters to prevent infestation was first recommended by Lintner (2).

Picking and destroying infested fruit was recommended by Bogue (6) in a general way. Slingerland (9) recommended the picking of grape berries infested by first-brood larvæ and also advised the destruction of the "trimmings."

Burying the hibernating pupæ by plowing was also first suggested by Slingerland (9).

Marlatt (3) first recommended spraying, but did so doubtfully, for at that time the berry moth was regarded as a general feeder. Following this both Beach (4) and Bogue (6) disparaged spraying as "of little value." Webster (5), however, observed that the pest could be controlled by spraying, and Felt (7) reported, as an incidental to rootworm control, that spraying had reduced the berry-moth infestation 50 per cent.

Slingerland's work, mentioned above, was followed by a number of important contributions. Gossard and Houser (11), in Ohio, recommended the addition of soap to an arsenical spray and the use of "trailers" in applying it. A thorough life-history study, the first upon which a satisfactory spray schedule could be based, was made by Johnson and Hammar (16) and a combination of control measures was recommended. Goodwin (19), in Ohio, recorded satisfactory results by spraying, using 3 pounds of arsenate of lead (powdered) to 50 gallons of liquid, an adhesive, and an application with "trailers." His spray schedule differed from the preceding by being directed largely against the second-brood larvæ.

CONTROL EXPERIMENTS AT NORTH EAST, PA.

Experiments to establish a control for the grape-berry moth, conducted at North East, Pa., were carried on in vineyards on a commercial scale whenever possible. Vineyards chosen for experimental work were those which had been infested heavily the previous season and as far as possible those in which the infestation had been distributed rather evenly.

To determine the degree of success of the different methods tried in vineyards, whenever it was feasible, counts were made of the sound and infested berries in the different experimental plats and in the adjacent untreated check plats. Counts of infested berries in each of the different plats were made the first season from four 40-pound crates of harvested fruit. In all plats in a single vineyard, the crates were taken from the same relative positions. During the following seasons a count was made from all of the fruit from 12 to 25 vines. These vines were taken at intervals throughout the length of each plat so as to include all conditions, and in the same relative positions in all plats in the same vineyard.

ELIMINATING VINEYARD CONDITIONS FAVORABLE TO THE GRAPE-BERRY MOTH.

Winter Exposure.

Protected situations in vineyards, along hedgerows, fences, or woodlots, and low-lying spots, are invariably more heavily infested by the berry moth than are the less protected portions of the same vineyard. On the other hand, exposed knolls seldom are infested heavily. This variability in infestation, according to Johnson and Hammar, is due to protection afforded to hibernating insects and the consequent reduction of winter mortality. Goodwin attributed the heavier infestation in low-lying spots to washing of cocoons in winter. Observations by the writer confirmed both these conclusions and also indicated that wind at the time of flight of moths is a factor, as moths drift with the wind into these low-lying spots.

Of these factors causing heavy infestation, one at least, winter protection in a vineyard, can be regulated more or less by artificial means. The importance of this factor was tested during the winter of 1915–16.

Different lots of cocoons, collected in the fall of 1915, were placed in cylindrical baskets of 20-inch wire mesh and wintered in vineyards in protected and in exposed situations, and also in the insectary yard under a covering of leaves held in place by wire screen. To forestall accidents each lot was divided into two baskets. In May, 1916, the cocoons were removed and placed in rearing jars. Table 1 shows the effect of the different conditions upon mortality:

Table 1.—*Percentage of emergence of the grape-berry moth hibernating in exposed and in protected situations.*

Lot No.	Situation.	Number of cocoons.	Number of moths emerged.	Emergence.
				Per cent.
I.	In vineyard, naturally exposed; crest of windswept knoll	350	20	5.71
II.	In vineyard, naturally protected by brush and drifted snow	350	86	24.05
III.	In vineyard, artificially protected by covering with 2 inches of earth	150	45	30.00
IV.	In insectary yard, artificially protected under "leaf blanket"	350	154	44.00

The rearing records show clearly the value of winter exposure in a vineyard in reducing the number of moths that will be present the following season.

A comparison of Lot III with Lot I shows how plowing, if injudiciously practiced, may increase vineyard infestation. If a furrow is thrown up to the vines in late fall, after the larvæ have spun their cocoons under the vines, it will give the hibernating pupæ winter protection. And if the earth is plowed away before the time of moth emergence, these artificially protected insects are released.

It is obvious that the protection of hibernating pupæ should be avoided whenever practicable. Plowing to the vines in late fall after harvest should be avoided as far as possible. Hedge rows and brush along vineyards should be removed. This last coincides with good vineyard practice and is of value also in reducing danger of leafhopper injury.

Unnecessary Shade.

Shade in a vineyard favors the berry moth. Where the growth is vigorous and the foliage dense, or where vines have been trained so as to give an unusual amount of shade, the infestation invariably is heavier than in adjacent parts of the vineyard or in vines giving less shade. Vigorous growth is desired, of course, but when horticultural considerations do not prevent, vine training systems which give unusual shade should be avoided.

DESTRUCTION OF LEAVES IN FALL.

Destruction of the hibernating generation in the cocoon, the first control measure to be recommended, was tried in the fall of 1914. In a small block in the McDonald vineyard the writer attempted removing cocoons by raking out the leaves under the trellis. Upon examination of the leaves thus collected it was found that practically all of the cocoons had fallen out. In the following season when counts of berries infested by first-brood larvæ were made no difference between this block and the check was noted.

During the seasons of 1914, 1915, and 1916 the writer and his associates collected approximately 30,000 cocoons for rearing. No system could be devised to aid in collecting these cocoons and the work was necessarily done by hand. It was always a slow and tedious process and is impracticable as a means of control, since the cocoons are usually spun, except in very dry seasons, in leaves that are sodden and ready to fall apart, and not in fresh, crisp leaves. Frequently the cocoons are spun in the leafage of chickweed and sorrel and in other leaves which ordinarily would escape collection.

BAGGING GRAPE CLUSTERS.

The bagging of grapes immediately after the setting of fruit, to prevent infestation by the berry moth, was tried in the season of 1914 in the vineyard of the late Mr. J. L. Spofford. Clusters on 25 vines were covered with paper bags, 2 and 3 pound sizes. The bags were fastened on the clusters with long pins and a slit was cut in the bottom of each bag to drain out whatever water might collect.

The experiment was successful in so far as exclusion of the moth was concerned. Only 20 wormy berries were found in 100 clusters which averaged 32 berries to the cluster. This was a total infestation of only 0.62 per cent. However, the test was not severe, for the infestation of the grapes on the surrounding vines was light, being only 13.2 per cent. The infestation of the bagged clusters was due no doubt to oviposition which had taken place before the bags had been placed on the clusters.

The cost of bagging, however, is prohibitive in commercial vineyards in the Erie-Chautauqua grape region. Brooks (10) records, in control measures against the grape curculio, that one laborer in his employ could bag 1,200 clusters a day. This was probably exceptionally fast work. Using this as a basis and figuring 550 vines per acre, each bearing 40 clusters, or a total of 22,000 clusters, the minimum cost of bagging an acre of grapes, according to 1914 prices, would be as follows:

Applying bags	$22.91
Cost of bags, $1.15 per 1,000	25.30
Pins, $0.10 per 1,000	2.20
Total	50.41

This method of control, if followed at all, would be practicable only in a garden vineyard.

HAND PICKING INFESTED BERRIES.

Attempts to control the grape-berry moth by hand picking the fruit infested by first-generation larvæ, in order to prevent subsequent infestation, were made in the seasons of 1914 and 1915. Clear-cut comparisons between the hand-picked plats and the checks were impossible because of the flight of moths from one row to another.

EXPERIMENT IN ADAMS AND GILL VINEYARD OF NORTH EAST, PA., 1914.

The plat chosen for the hand-picking experiment was a narrow strip of eight rows, containing slightly more than 1 acre, located in a corner of the vineyard, and bordered by a hedgerow. This plat was from three to four times as grossly infested as was the greater part of the vineyard. After the six rows nearest the hedge, the percentage of infestation declined quite rapidly as compared with that of the rest of the vineyard, and the south end, which was lower than the rest of the plat, was even more heavily infested than the rows next to the hedge.

Hand picking of wormy fruit was done July 7 and 8 and again between July 25 and August 1. The time of the first picking occurred about 10 days after the falling of the blossoms. The actual time expended in this work was 35.5 hours for the two men employed, or a total of 71 hours. The second picking, which was more or less interrupted by rain, developed that about 12 per cent of the berries were wormy.

The counts of wormy berries taken at harvest time showed the following percentages of infestation:

	South end.	North end.
	Per cent.	*Per cent.*
Hand-picked plat	84.4	24.9
Check	68.2	25.3

This shows as a curious result that the hand-picked area was more heavily infested than the check, probably owing to the flight from the vineyard at large of moths which settled in this narrow protected area.

EXPERIMENT IN MOORHEAD VINEYARD, MOORHEADVILLE, PA., 1914.

A plat of 16 rows, 2 acres in area, was chosen in the middle of the vineyard of the late R. E. Moorhead. The infestation was comparatively uniform throughout. Hand picking of infested fruit was done three times, July 2 and 3, again from July 17 to 21, and again from August 10 to 15. The total time occupied in treating the 2 acres was 55 hours, or 27½ hours per acre.

Counts of infested berries from four crates of grapes from the hand-picked plat were made and the same from the check plat. The following shows the percentage of infestation:

Hand picked	14.7 per cent.
Check	27.4 per cent.

EXPERIMENT IN THE McDONALD VINEYARD, NORTH EAST, PA., 1915.

The heavily infested ends of 12 rows of a vineyard section adjoining a woodlot were chosen for this experiment. The picked area extended along the rows about 70 feet. The plat was picked over once, August 5 and 6, requiring a total of 22 hours' work for approximately one-fifth of an acre.

Counts taken just before harvest from representative vines in the hand-picked plat and in the check plat showed the following results:

TABLE 2.—*Counts in hand-picking experiment, McDonald vineyard, North East, Pa., 1915.*

Plat.	Number of vines.	Number of clusters.	Number of berries.	Infested berries.	Infested berries per 100 clusters.	Infestation.
						Per cent.
Hand picked	12	520	13,664	2,592	498.4	18.12
Check	12	546	16,513	6,162	1,136.6	34.93

EXPERIMENT IN THE MOORHEAD VINEYARD, MOORHEADVILLE, PA., 1915.

A plat of 22 rows, comprising nearly 3 acres, part of which had been hand picked in the experiment in 1914, was chosen for experimental work. No difference in infestation was shown in the two parts of this plat, probably because the effect of the work of the previous season had been obscured by the flight of moths from one part to another. However, the cumulative results probably were of considerable value, as the infestation in this section of the vineyard was much lighter than it had been the previous season, while the infestation of the vineyard as a whole was about the same.

The plat was hand picked only once for infested berries, between July 30 and August 5, the time required being lengthened by rain. The actual labor required was 43 hours.

Counts taken just before harvest on 12 representative vines in the hand-picked plat and in the check plat showed the following results:

TABLE 3.—*Counts in hand-picking experiment, Moorhead vineyard, North East, Pa., 1915.*

Plat.	Number of vines.	Number of clusters.	Number of berries.	Infested berries.	Infested berries per 100 clusters.	Infestation.
						Per cent.
Hand picked	12	408	11,793	945	242.3	8.01
Check	12	360	11,793	1,677	465.8	14.22

DISCUSSION.

An average, from the different experimental plats, of the time required to hand pick the "wormy" berries in an acre of grapes was 55.75 hours. At 12½ cents per hour the cost per acre would be $6.97.

This method, hand picking wormy berries, was employed in a number of vineyards by the owners during the seasons of 1914 and 1915 and as a rule the beneficial results were not readily apparent. In several instances the value of the work was reduced by picking the berries after most of the "worms" had left the grapes, and in others by inefficient laborers who missed a large percentage of the "wormy" berries. In some cases the infestation probably was considerably reduced and in one instance apparently successful control resulted. In this vineyard the infestation was restricted to a narrow strip comprising a few rows which were hand picked by the owner himself about once a week.

From the experiments and observations of the two seasons, hand picking of "wormy" berries could be relied upon to reduce berry-moth infestation but not to control it. The difficulty of securing ample and efficient labor at a time when it is needed stands in the way of adopting hand picking as a general method of repression, and the ultimate cost is thus too high when only partial control may be expected. It might be of use in a garden vineyard or in a commercial vineyard where only a small area is infested, but on the whole it can not be regarded as a satisfactory remedial measure.

EARLY HARVESTING.

Early harvesting of grapes and removal of the "trimmings" remove great numbers of berry-moth larvæ which otherwise would be left to overwinter in the vineyard. This practice is limited, for the grape harvest usually continues long after a majority of the berry-moth larvæ have cocooned. However, it should be applied to the worst infested areas in the vineyard.

The degree of reduction of hibernating pupæ by comparatively early harvesting is best shown by counting cocoons under vines. During the harvest of 1915, which was an extremely late season, one part of the edge of a vineyard, where the infestation was approximately 50 per cent, was picked October 12 to 15, and all grapes were removed; the other part was picked October 24 to 26. The count of cocoons under 14 vines from each block was as follows:

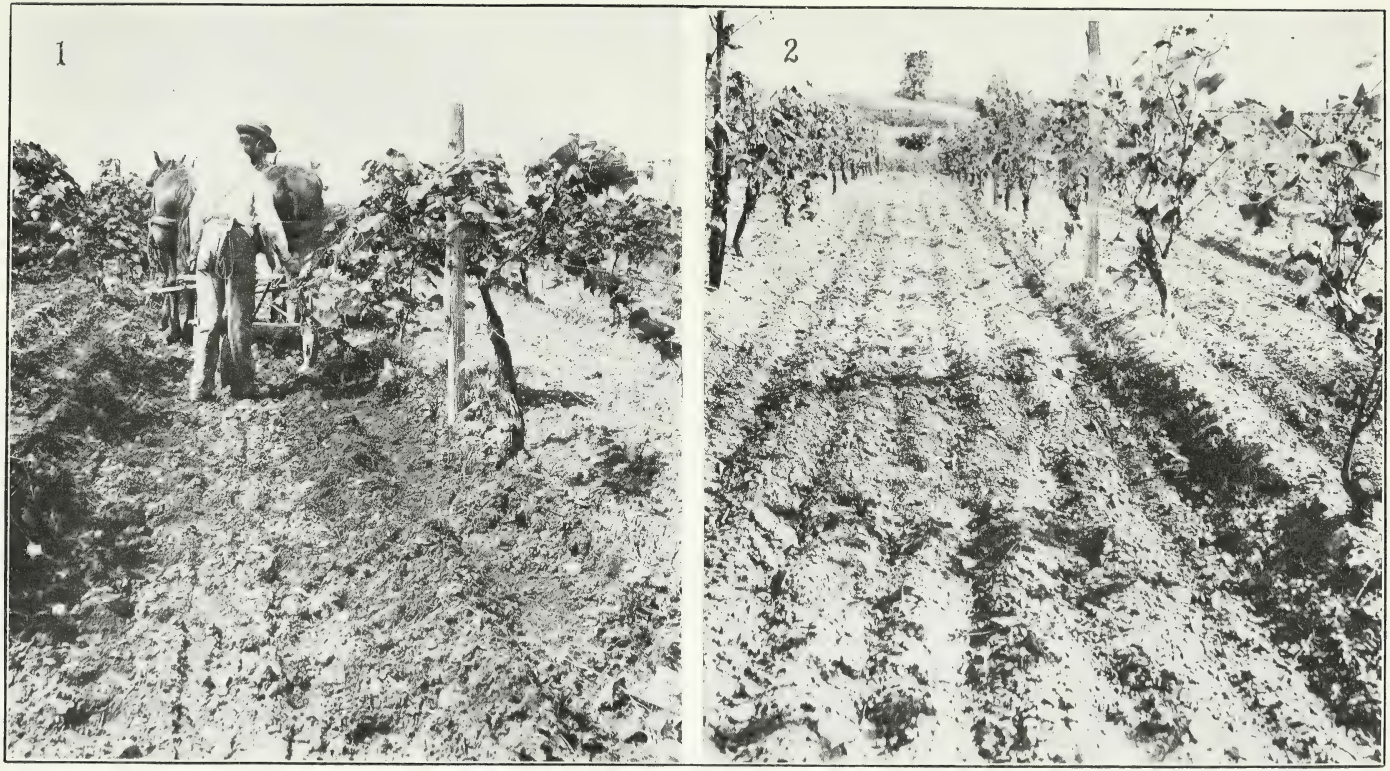
Date picked.	Number of vines.	Cocoons found under vines.	Cocoons per vine.
Oct. 12 to 15	14	92	6.59
Oct. 24 to 26	14	621	44.50

As stated, this was an exceptionally late season. During the season of 1916, according to the records, half the larvæ had left the grapes by October 4. Johnson and Hammar found that during normal seasons the majority of the berry-moth larvæ left the grapes by October 10.

Early harvesting is more valuable in avoiding loss of weight in the crop attacked than in reducing the following season's infestation. Grapes badly infested with the berry moth lose weight rapidly after the picking season begins, owing to the movement of larvæ from infested to sound berries, and to the subsequent shrinking of previously infested berries.

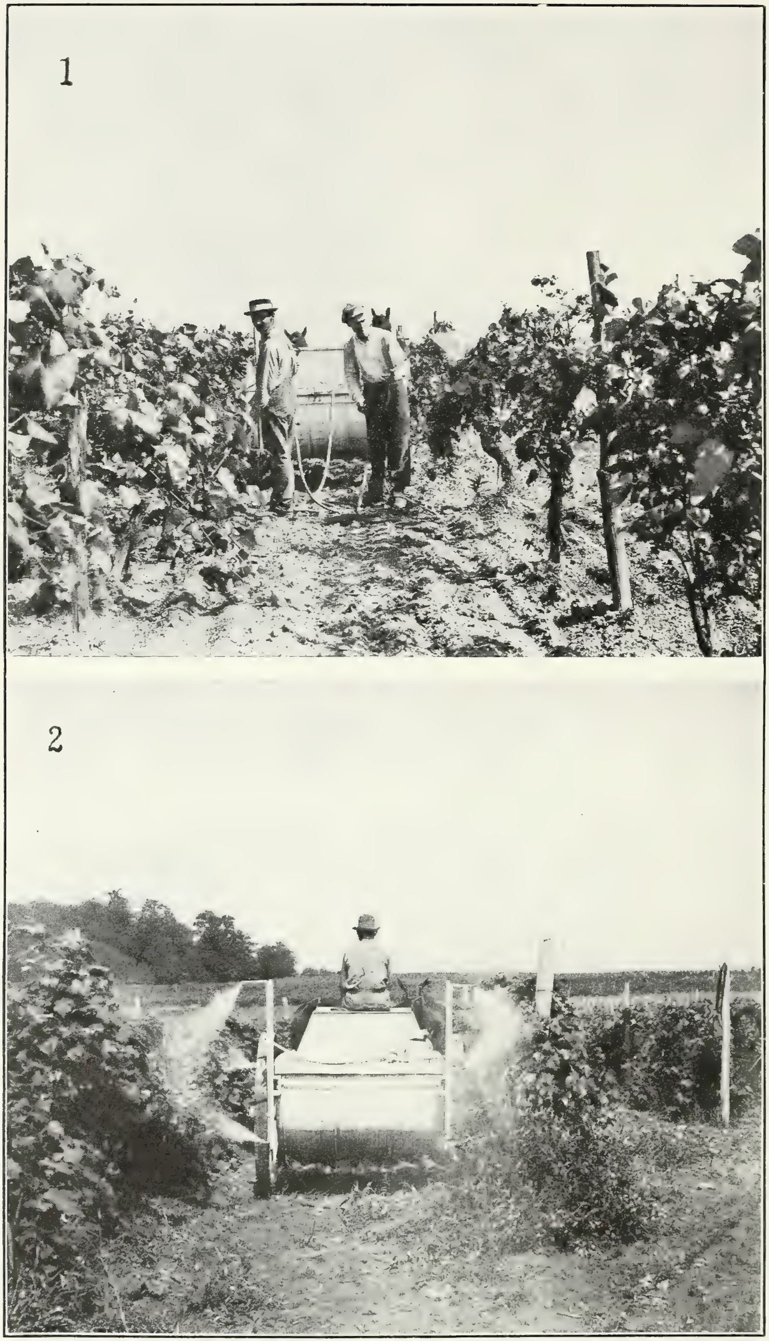
BURYING HIBERNATING PUPÆ.

"Plowing under" the hibernating generation previous to the time of moth emergence and keeping it covered during the earlier part of this period had been practiced for a number of years in the vicinity of North East, Pa., although no definite knowledge as to the effectiveness of the practice had yet been ascertained. (See Plate IV.) In late fall or early spring earth is thrown up by a plow to the vines on both sides covering the hibernating pupæ under several inches of earth. This earth is allowed to remain until after the general emergence of moths in the spring, when it is removed with a horse-hoe.



CULTURAL METHODS AGAINST THE GRAPE-BERRY MOTH.

FIG. 1.—Removing ridge of earth under trellis with horse hoe. FIG. 2.—Ridge of earth before horse hoeing. (Original.)



SPRAYING AGAINST THE GRAPE-BERRY MOTH.

FIG. 1.—"Trailer" method of applying spray. FIG. 2.—"Set nozzle" method of applying spray. (Original.)

The effect of this treatment is to prevent the moths from escaping through the covering of earth.

In a number of vineyards where this method of control has been practiced, check rows were maintained in which the earth was removed early in the season, in order to determine, if possible, the effects of the practice. No definite results were obtained. If small checks were left the flight of moths obscured the results altogether; and in larger checks variation of infestation interfered. In some vineyards the infestation appeared to be reduced greatly, but in none was it controlled.

The principle of this practice was proven correct, however, by a small experiment in the insectary yard during the season of 1916.

Three lots of 300 cocoons each, collected in the fall of 1915 and wintered in the insectary yard, were placed in 8-inch flowerpots. Two lots were covered with from 2½ to 3 inches of earth; the third was left uncovered. The emergence record totals as follows:

From 600 cocoons buried under earth no moths emerged.
From 300 cocoons not buried 103 moths emerged.

In a number of small lots 60 cocoons were placed in glass vials where the action of the moths after emergence could be observed. These cocoons were covered with earth at depths varying from ½ inch to 3 inches. Upon emergence none of the moths were able to work their way upward through the covering of earth. It should be remembered, however, that results as satisfactory as these can not be expected under field conditions.

"Horse hoeing" away from the vines, if done during the grape blossoming period, would also destroy grape-rootworm pupæ which are transforming at that time (13, 18).

SPRAYING.

Experiments with poison sprays were conducted during each of the three seasons. All of the vineyards but one were planted to Concord grapes, which is the standard variety for this grape-producing region. In 1916 experiments were conducted also in a single vineyard of Niagara grapes.

Weather conditions affecting spraying operations and results differed strikingly during the three seasons. Records from the Weather Bureau station at Erie, Pa., on Lake Erie, 16 miles west of North East, showed that in 1914 the months of July and August were nearly normal. The next year was colder with excessive rains during these two months, while the corresponding period of 1916 was very warm and dry. The average mean temperature for these two months in 1915 was 2.4° below normal and the rainfall was 7.95 inches above normal. In 1916 the average mean temperature was 3.7° above normal and the rainfall was 3.39 inches below normal.

In rainfall during these two months the two seasons showed a difference of 11.34 inches.

METHODS OF APPLICATION.

All spray applications were made with a gasoline-power sprayer. Two methods of applying the spray were used. (See Pl. V.) By the one, spray was applied to the vines by a "set-nozzle" arrangement at the rear end of the machine. From vertical pipes on each side of the machine two short spurs were directed outward, each bearing an angle nozzle which drove the spray outward and upward and as far as possible under the leaves. The lower spur was below the lowest wire of the trellis. The height of this spur could be varied somewhat to suit the trellis. A third and upper nozzle was mounted on a longer spur and projected over the trellis, the nozzle being directed downward. The "set-nozzle" method of application of spray is more generally used against the grape rootworm and mildew, because it is least expensive from the labor standpoint.

By the other method single nozzles were mounted on short rods attached to the machine by trailing hose, and the spray was directed to the grape clusters by hand. This "trailer" method has been recommended by Johnson in his investigations against the grapevine leafhopper.

The two methods require about the same amount of spray material per acre. When "set nozzles" were used about 150 gallons of spray was applied per acre; with "trailers," about 125 gallons per acre was used immediately after the falling of the blossoms, and about 175 gallons when the berries began to touch.

When applications were made with "set nozzles" the machine was driven along every row, but when "trailers" were used the machine was usually driven only along alternate rows, the rodman on each side being able to reach through the trellis and spray both sides of the row.

The spraying schedules followed in these investigations were based largely on the seasonal-history studies on the grape-berry moth made by Johnson and Hammar, modifications being made the second and third seasons.

SPRAYING EXPERIMENTS IN 1914.

From a control standpoint the spraying in 1914 was a failure, although it did bring about a consistent reduction in the numbers of the berry moths. Furthermore, results in the Phillips vineyard were of uncertain value because of the wide variation of infestation as shown by the checks. The negative results were of value, however, since they indicated the necessity of a radical revision of spraying practice.

In applying the spray, the difficulty in covering the grape clusters with "set nozzles" was apparent. It was noted also that even when the spray was applied directly to the grape clusters with "trailers" it did not adhere to the waxy skin of the grape berries, except when the solution to which soap had been added was used. These features, (1) the application of the spray directly to the grape clusters and (2) the addition of soap to the solution, were the most important changes which were suggested by this season's work.

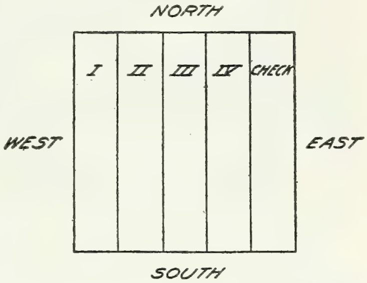


FIG. 1.—Diagram showing arrangement of experimental plats in Mr. J. M. Moorhead's vineyard, Moorheadville, Pa., 1914. (Original.)

EXPERIMENT IN THE MOORHEAD VINEYARD, MOORHEADVILLE, PA., 1914.

Experimental work in the Moorhead vineyard was conducted in a section of 38 rows, comprising about 5 acres, which was divided into 4 plats of 8 rows each and one of 6 rows, the latter used as the check plat. The arrangement of the plats is shown in the diagram (fig. 1). The vineyard was rather evenly infested throughout.

TABLE 4.—*Spray mixtures used, methods and dates of application, and percentages of infestation in experimental plats, Moorhead vineyard, Moorheadville, Pa., 1914.*

Plat No.	Dates sprayed with set nozzles.	Dates sprayed with trailers.	Arsenate of lead (paste).	Bordeaux mixture.		Laundry soap.	Water.	Infestation.
				Lime.	Copper sulphate.			
			Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Gallons.*	*Per cent.*
I	June 9, 23, and July 9		3	3	3		50	25.6
II	June 23 and July 9		3	3	3		50	26.7
III	June 23	July 9	3	3	3		50	27.8
IV	do	July 10	3	3	3	[1] 1	50	22.9
Check, unsprayed.								31.8

[1] Last application only.

Though the experiments in this vineyard showed a consistent reduction of infestation, definite control of the grape-berry moth was not established. In one plat the results appeared somewhat more favorable than in the others and offered a suggestion for further investigation. Soap was added to the spray mixture and "trailers" were used in applying it, but as these changes had been made only for the last application they could not affect the results materially.

EXPERIMENT IN THE PHILLIPS VINEYARD, NORTH EAST, PA., 1914.

Experimental work in the Phillips vineyard was conducted in a section which included 44 rows, covering about 7 acres. It was divided into 7 plats of 6 rows each. The middle row of each plat and the two rows at one side were chosen for checks. The arrangement of the plats is shown in the diagram (fig. 2).

TABLE 5.—*Spray mixtures used, methods and dates of application, and percentages of infestation in experimental plats, Phillips vineyard, North East, Pa., 1914.*

Plat No.	Dates sprayed with set nozzles.	Dates sprayed with trailers.	Arsenate of lead (paste).	Bordeaux mixture.		Laundry soap.	Nicotine sulphate.	Water.	Infestation.
				Lime.	Copper sulphate.				
			Lbs.	*Pounds.*	*Pounds.*	*Pounds.*	*Pints.*	*Galls.*	*Per ct.*
I	June 12, 26, and July 12		3	3	3			50	5.2
II	June 26 and July 12		3	3	3			50	4.5
III	June 26	July 12	3	3	3			50	7.2
Check A									8.7
IV	June 26 and July 12		3	3	3	[1] 1		50	9.5
V	June 26	July 12	3	3	3	[1] 1	[1] 1¼	50	5.5
VI	June 26	July 12	3	3	3	[1] 1		50	17.9
Check B									52.4

[1] Last application only.

The infestation in this vineyard had been very heavy the previous season, but in 1914 it was light. Check plat B was much more heavily infested than the adjacent sprayed plat, whereas this plat was much more heavily infested than check plat A. While it is probable that spraying did reduce the infestation somewhat in this plat and in the one next to it, because of the wide variation of infestation in the unsprayed checks, this can not be stated definitely. The similarity of results in check plat A and the sprayed plats adjoining it indicates failure in control.

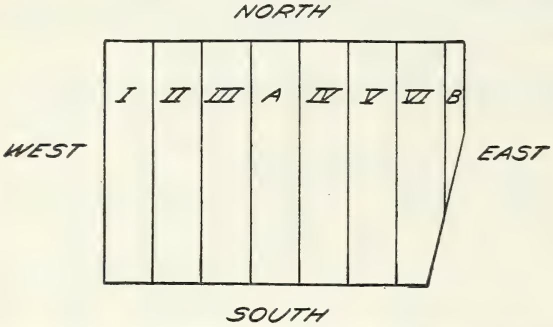


FIG. 2.—Diagram showing arrangement of experimental plats in Mr. M. D. Phillip's vineyard, North East, Pa., 1914. Sprayed plats are marked with Roman numerals, check plats with letters. (Original.)

SPRAYING EXPERIMENTS IN 1915.

The season of 1915 was marked by extremely heavy rainfall during the spraying season and during the month following. Spraying operations were interrupted frequently or delayed by rain and as a result spraying as a remedial measure was put to a very severe test. However, when the final counts were made, all plats sprayed with solutions containing arsenate of lead and soap and applied with "trailers" showed a satisfactory reduction of infestation from a commercial standpoint. The contrast in infestation between the sprayed plats and others was commented on with astonishment at harvest time by pickers who were ignorant that any remedial measures had been employed. Tables 6 and 7 will give in detail the treatments applied in the different vineyards and the results as shown by percentages of "wormy" fruit.

EXPERIMENT IN THE BARTLETT VINEYARD, NORTH EAST, PA., 1915.

Experimental work in this vineyard was conducted in a square corner section of about 2 acres which had been very heavily infested in 1914. It was divided into two large plats of 11 rows each with an 8-row check between and 2 narrow plats of 3 rows each outside of the larger ones. The adjacent vineyard also was unsprayed and used as a check. The arrangement of plats is shown in the diagram (fig. 3).

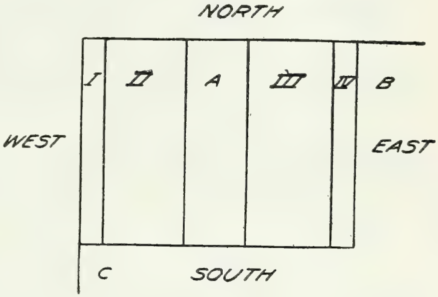


FIG. 3.—Diagram showing arrangement of experimental plats in the vineyard of Mr. A. P. Bartlett, North East, Pa., 1915. The sprayed plats are marked with Roman numerals and the check plats with letters. (Original.)

TABLE 6.—*Spray mixtures used and method and dates of application in experimental plats, Bartlett vineyard, North East, Pa., 1915.*

Plat No.	Dates of spraying.	Arsenate of lead (paste).	Bordeaux mixture.		Laundry soap.	Nicotine sulphate.[1]	Water.	Method of application.	Remarks.
			Lime.	Copper sulphate.					
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pints.*	*Gallons.*		
I........	July 6, 19	3	3	3	1	¼	50	Trailers.	Double sprayed.[2]
II.......	...do.......	3	3	3	1	¼	50	...do.....	Single sprayed.[2]
III......	...do.......	5	3	3	1	¼	50	...do.....	Single sprayed.[2]
IV.......	...do.......	5	3	3	1	¼	50	...do	Double sprayed.[2]

[1] Last application only.

[2] Plats marked "double sprayed" were sprayed twice on each date of treatment, the second spray being applied as soon as the first had dried.

TABLE 7.—*Percentage of infestation in experimental plats, Bartlett vineyard, North East, Pa., 1915.*

Plat No.	First brood.					Second brood.				
	Number of vines.	Number of clusters.	Total berries.	Infested berries.	Infestation.	Number of vines.	Number of clusters.	Total berries.	Infested berries.	Infestation.
					Per cent.					*Per cent.*
I................	20	1,024	29,036	572	1.97	15	768	21,760	849	3.9
II...............	20	1,132	31,314	572	2.71	15	849	23,489	963	4.1
Check A.........	20	1,124	30,568	2,404	7.86	15	843	22,926	3,372	14.8
III..............	20	1,330	38,676	375	.97	15	997	29,066	313	1.2
IV..............	20	1,192	41,107	124	.30	15	894	30,830	68	.23
Check B........	20	1,051	29,567	1,943	6.57	15	788	22,175	3,925	17.7
Chock C.........	20	832	21,356	1,743	8.16	15	624	16,016	1,399	46.2

On all sprayed plats where poison with adhesive had been applied with "trailers" the control was effective. Plats I and II on which arsenate of lead (paste) had been applied at the rate of 3 pounds to 50 gallons of liquid were infested more heavily than Plats III and IV, on which arsenate of lead at the rate of 5 pounds to 50 gallons had been applied. The infestation was naturally heavier on the west side, however, as is shown by a comparison of the unsprayed plats. Double spraying appeared to reduce the infestation but not enough to offset the extra cost of application.

EXPERIMENT IN THE MILLER AND CARLBURG VINEYARD, NORTH EAST, PA., 1915.

The experimental plat in this vineyard included 64 rows covering about 10 acres. It was divided into 10 plats of 6 rows each, the 4 remaining rows being left for check. This plat was surrounded on all sides by vineyard, two parts of which were used as checks also. The arrangement of plats is shown in the diagram (fig. 4). Spraying operations for both first and second applications in this vineyard were interrupted and delayed by frequent rains.

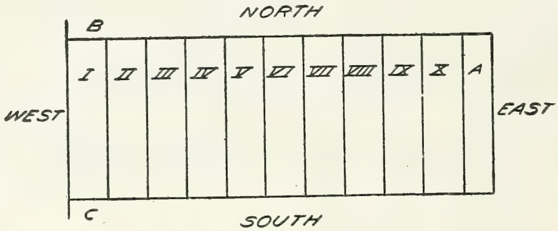


FIG. 4.—Diagram showing arrangement of experimental plats in the vineyard of Messrs. G. H. Miller and A. I. Carlburg, North East, Pa., 1915. The sprayed plats are marked with Roman numerals and the check plats with letters. (Original.)

TABLE 8.—*Spray mixtures used and methods and dates of application in experimental plats, Miller and Carlburg vineyard, North East, Pa., 1915.*

Plat No.	Dates of spraying.	Arsenate of lead (paste).	Bordeaux mixture.		Laundry soap.	Fish-oil soap.	Flour paste.	Nicotine sulphate.	Water.	Method of application.
			Lime.	Copper sulphate.						
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pints.*	*Gallons.*	
I	July 2, 15	3	3	3	1				50	"Trailers."
II	July 2, 15	5	3	3		2			50	Do.
III[1]	July 2, 15	3				2			50	Do.
IV	July 3, 16	3	3	3	1				50	Do.
V	July 3, 16	3	3	3		2		¼	50	Do.
VI	July 3, 16	3	3	3	1			¼	50	Do.
VII	July 3, 17		3	3	1				50	Do.
VIII	July 5, 17	3	3	3			2		50	Do.
IX	July 5, 17	3	3	3					50	Do.
X	July 5, 17	3	3	3		2			50	"Set nozzles."

---

[1] Rain followed immediately after the second spray application on this plat and apparently washed off most of the spray.

Table 9.—*Percentage of infestation in experimental plats, Miller and Carlburg vineyard, North East, Pa., 1915.*

Plat No.	First brood.					Second brood.				
	Number of vines.	Number of clusters.	Total berries.	Infested berries.	Infestation.	Number of vines.	Number of clusters.	Total berries.	Infested berries.	Infestation.
					Per ct.					*Per ct.*
I	25	601	14,028	450	3.21	20	481	10,822	847	7.91
II	25	544	12,550	414	3.29	20	435	9,640	951	9.86
III	25	492	11,235	519	4.53	20	397	9,088	2,887	31.77
IV	25	460	13,692	343	2.51	20	368	10,956	432	3.94
V	25	575	13,705	289	2.11	20	460	10,960	967	9.56
VI	25	796	19,544	479	2.45	20	637	15,625	1,188	7.60
VII	25	712	22,736	1,264	5.99	20	570	16,587	5,523	33.31
VIII	25	661	18,508	795	4.18	20	529	14,783	2,793	18.89
IX	25	561	16,269	901	5.53	20	459	13,005	2,738	21.05
X	25	716	21,480	1,024	4.53	20	513	15,441	3,152	20.41
Check A	25	695	20,850	1,013	4.86	20	556	14,430	3,958	28.80
Check B	25	792	23,882	3,533	14.87	20	634	19,135	11,803	61.67
Check C	....	....	....	....	....	10	340	9,380	4,710	50.21

In spite of the exceedingly adverse weather conditions at the time of spraying, all plats but one on which arsenate of lead with soap had been applied twice with "trailers" (Plats I, II, IV, V, and VI) showed a satisfactory reduction of the grape-berry moth from a commercial standpoint. In one plat where rain followed immediately after the second spray application (Plat III) the results must be disregarded. The rain also probably reduced the efficiency of control in Plat II, which was sprayed just before Plat III, and to a less degree may have affected others; but the results showed that when the spray had time to dry on the grape berries before rain, a fairly satisfactory control could be secured. Failure to control resulted in plats where spray was applied with "set nozzles" instead of "trailers" (Plat X), where the soap was omitted from the spray mixture (Plat IX), and where flour paste was used as adhesive instead of soap (Plat VIII). Bordeaux mixture and soap were used without arsenate of lead (Plat VII) and no effect, repellent or insecticidal, was noted. Nicotine sulphate appeared to add nothing to the effectiveness of the solution (Plats V and VI). Laundry soap (Plats I, IV, and VI) and fish-oil soap (Plats II and V) were both used apparently without distinct advantage for either. The plat sprayed with 5 pounds of arsenate of lead (paste) to 50 gallons of liquid (Plat II) was much more heavily infested than the plat sprayed with only 3 pounds of arsenate of lead (paste) to 50 gallons (Plat IV), but as the second application of spray on Plat II was closely followed by rain the infestation in this plat was probably also somewhat heavier naturally. (Compare check plats B and C with A.)

EXPERIMENT IN THE MOORHEAD VINEYARD, MOORHEADVILLE, PA., 1915.

The experimental work in the Moorhead vineyard was conducted in the same section as in 1914, but the arrangement of plats was somewhat changed. The plat that had the lightest infestation was chosen as check, while the check of the 1914 season was sprayed. The adjacent sections of the vineyard were sprayed once by the owner, soon after July 1, with arsenate of lead (paste), 3 pounds, and Bordeaux mixture, 50 gallons, to control the grape rootworm; the spray was applied with "set nozzles." Counts were made from these sections adjacent to the experimental block and they are recorded as checks, B and C. The arrangement of plats is shown by the diagram (fig. 5).

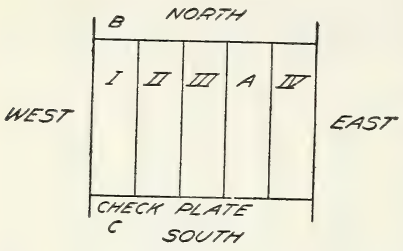


Fig. 5.—Diagram showing arrangement of plats in the vineyard of Mr. J. M. Moorhead, Moorheadville, Pa., 1915. The sprayed plats are marked with Roman numerals and the check plats with letters. (Original.)

Table 10.—*Spray mixtures used and methods and dates of application in experimental plats, Moorhead vineyard, Moorheadville, Pa., 1915.*

Plat No.	Dates of spraying.	Arsenate of lead (paste).	Bordeaux mixture.		Laundry soap.	Nicotine sulphate.	Water.	Method of application.
			Lime.	Copper sulphate.				
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pints.*	*Gallons.*	
I	July 1, 20	3	3	3	1	....	50	Sprayer ("trailer") driven in alternate alleys.
II	July 1, 20	5	3	3	1	....	50	Every alley.
III	July 1, 20	3	3	3	1	¼	50	Alternate alleys.
IV	July 1, 21	3	3	3	1	....	50	Every alley.

Table 11.—*Percentage of infestation in experimental plats, Moorhead vineyard, Mooreheadville, Pa., 1915.*

Plat No.	Number of vines.	Number of clusters.	Total berries.	First brood.		Second brood.	
				Infested berries.	Infestation.	Infested berries.	Infestation.
					Per cent.		*Per cent.*
I	20	820	29,130	90	0.31	1,099	3.77
II	20	975	34,450	112	.32	717	2.08
III	20	726	22,411	49	.22	943	4.21
Check A	20	975	25,512	903	3.54	4,860	19.05
IV	20	813	26,350	141	.54	1,070	4.06
Check B	20	785	21,951	715	3.25	4,997	22.81
Check C	20	756	22,478	822	3.65	7,736	34.86

The final counts show that the grape-berry moth had been controlled in all sprayed plats. In this respect they contrast sharply with the previous season's results in the same vineyard. The only essential differences between the treatments of this season and those of the previous one were the addition of soap to the spray mixture and the application of the spray with "trailers" instead of with "set nozzles."

The results further indicate that 3 pounds of arsenate of lead (paste) was practically as effective as 5 pounds to 50 gallons of liquid, and that no special advantage or injury resulted from the addition of nicotine sulphate to the spray mixture. Also that drawing the sprayer in every alley and each rodman spraying only one side of a row at a time had no advantage over driving up alternate alleys with each rodman spraying both sides of a row at one time.

Spraying Experiments in 1916.

Confirmation of the 1915 results was the most important feature of the season's work. Although infestation by the grape-berry moth was much heavier, the season was more favorable for work and the control measures were more effective.

EXPERIMENTS IN THE BARTLETT VINEYARD, NORTH EAST, PA., 1916.

The experimental work in Mr. A. P. Bartlett's vineyard was conducted in two sections differing in distribution of the berry moth. In both sections the rows ran north and south, but the checks were arranged differently. In the upper section the 1915 infestation was much the heavier on the west side, consequently the checks were not chosen in the usual way but instead a transverse check of the end 6 vines on all rows was left unsprayed. The arrangement of plats is shown by the diagram (fig. 6).

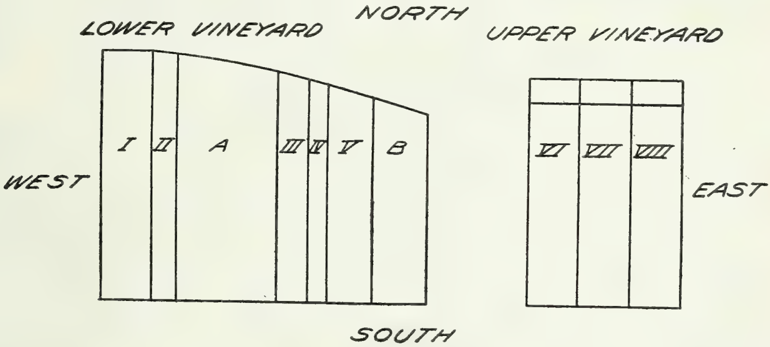


Fig. 6.—Diagram showing arrangement of experimental plats in vineyard of Mr. A. P. Bartlett, North East, Pa., 1916. In the lower vineyard the sprayed plats are marked with Roman numerals and the check plats are lettered. (Original.)

TABLE 12.—*Spray mixtures used and method and dates of application in experimental plats, Bartlett vineyard, North East, Pa., 1916.*

Plat No.	Date sprayed.	Arsenate of lead (powder).	Bordeaux mixture.		Laundry soap.	Resin fish-oil soap.	Potash fish-oil soap.	Water.	Method of application.
			Lime.	Copper sulphate.					
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Gallons.*	
I	July 22	1½	3	3	1			50	"Trailers."
II	Aug. 12	2½	3	3		1		50	Do.
III	July 6, 25	1½	3	3		1		50	Do.
IV	July 6, 25 and Aug. 12.	1½	3	3	1			50	Do.
V	July 5, 21	1½	3	3	1			50	Do.
IV	July 6, 21	2½	3	3	1			50	Do.
VII	July 5, 21	1½			1			50	Do.
VIII	July 5, 22	1½	3	3			2	50	Do.

TABLE 13.—*Percentage of infestation in experimental plats, Bartlett vineyard, North East, Pa., 1916.*

Plat No	Number of vines.	Number of clusters.	Total berries.	First brood.		Second brood.	
				Infested berries.	Infestation.	Infested berries.	Infestation.
Lower.					*Per cent.*		*Per cent.*
I	20	532	17,556	1,708	9.72	2,970	16.92
II	20	424	12,720			2,486	19.97
Check A	20	415	12,450	858	6.64	6,913	55.53
III	20	389	11,281	228	2.02	243	2.14
IV	20	390	11,700			81	.68
V	20	411	11,508	145	1.26	182	1.57
Check B	20	460	12,420			10,909	79.72
Upper.							
VI	20	474	15,168	320	2.11	768	5.06
Check VI	6	111	3,330	717	21.53	3,158	94.83
VII	20	681	18,068	199	1.10	724	4.01
Check VII	6	200	7,200	452	6.27	6,380	88.74
VIII	20	512	14,336	69	.48	67	.47
Check VIII	6	214	6,848	263	3.84	1,764	25.76

The final counts in this vineyard showed satisfactory results in all plats on which two applications of arsenate of lead with soap had been made (Plats III, V, VI, VII, and VIII). Where, in addition to these two applications, a third application was made, directed solely against the second brood, the percentage of infested fruit was slightly reduced, but since the result was so satisfactory with two sprays (compare Plat IV with III and V) an extra or third application was unnecessary. As an additional disadvantage, the fruit thus sprayed was badly stained at harvest time. A single application made at the time when the grape berries were just touching (Plat I) effected a marked reduction of infestation, as did a later single application directly solely against the second brood (Plat II), but in both plats the results were far from satisfactory. Any late application is open thus to objection because of staining the fruit at the approaching harvest. Three adhesives, laundry soap (Plat V), resin fish-oil soap (Plat III), and fish-oil soap without resin (Plat VIII), were used. The difference in infestation in these plats was so slight that it is not worthy of special consideration. Resin fish-oil soap solution spread rapidly and could be applied most easily. Arsenate of lead when used at the rate of 2½ pounds (powder) to 50 gallons of liquid (Plat VI) did not appear more effective than when used at the rate of 1½ pounds to 50 gallons. The solution in which Bordeaux mixture was omitted (Plat VII) was practically as effective as any other, although slight burning followed its application.

EXPERIMENT IN THE SOUTHWICK VINEYARD, NORTH EAST, PA., 1916.

A plat of 28 rows, 9 rows to the acre, was chosen for experimental purposes in this vineyard. An unsprayed check of 8 rows was left in the middle of the plat. On one side were two sprayed plats of 6 rows each, and on the other side two plats of 4 rows each. The rest of the vineyard section on either side of the experimental block, although sprayed for the grape rootworm by the owner, also served as a check. The arrangement of these plats is shown by the diagram (fig. 7).

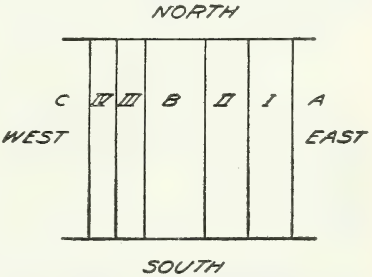


FIG. 7.—Diagram showing arrangement of experimental plats in the vineyard of Mr. B. T. Southwick, North East, Pa., 1916. The sprayed plats are marked with Roman numerals and the check plats with letters. (Original.)

During the season of 1915 this section had been heavily infested, from 30 to 40 per cent, with a tendency for the infestation to be heaviest at the north end.

TABLE 14.—*Spray mixtures used and methods and dates of application, Southwick vineyard, North East, Pa., 1916.*

Plat No.	Date sprayed.	Arsenate of lead (powder).	Bordeaux mixture.		Nicotine sulphate, 40 per cent.[1]	Laundry soap.	Water.	Method of application.
			Lime.	Copper sulphate.				
		Pounds.	*Pounds.*	*Pounds.*	*Pints.*	*Pounds.*	*Gallons.*	
I	July 10, 24.	1½	3	3	¼	1	50	"Trailers."
II	do	2½	3	3	¼	1	50	Do.
III	July 24.	1½	3	3	¼	1	50	Do.
IV	July 10, 24.	1½	3	3	¼	1	50	"Set nozzles" first application, "Trailers" second.

[1] Last application only.

TABLE 15.—*Percentage of infestation in experimental plats, Southwick vineyard, North East, Pa., 1916.*

Plat No.	Number of vines.	Number of clusters.	Total berries.	First brood.		Second brood.	
				Infested berries.	Infestation.	Infested berries.	Infestation.
					Per cent.		*Per cent.*
Check A	20	609	16,443	2,866	17.43	11,635	70.76
I	20	570	15,960	565	3.41	1,339	8.43
II	20	638	19,778	597	3.02	835	4.22
Check B	20	623	15,575	2,129	13.61	11,706	75.16
III	20	585	14,625	1,364	9.32	4,966	33.95
IV	20	584	16,936	995	5.87	3,242	19.13
Check C	20	608	15,200	1,073	7.06	9,963	65.65

The final counts in this vineyard showed that the grape-berry moth had been controlled in the plat where two applications with "trailers" had been made, using arsenate of lead (powder) at the rate of 2½ pounds to 50 gallons with an adhesive (Plat II). This was in the face of a very heavy infestation in the checks. In contrast to the results in all other vineyards, in the plat in which 1½ pounds of arsenate of lead (powder) was used the final count was distinctly less satisfactory (Plat I). This difference was conspicuous only at the north end of the vineyard, where the infestation in the checks was practically total and where several eggs had been deposited on a majority of the berries. It should be noted that the contrast was not apparent until the second-brood counts were made, and the first-brood infestation was about the same in both plats. An unusually large percentage of second-brood larvæ found in Plat I were very late, indicating that the early second brood had failed to enter the berries. This would indicate that the two amounts of poison were equally effective for some time, but that the higher amount withstood the weathering better.

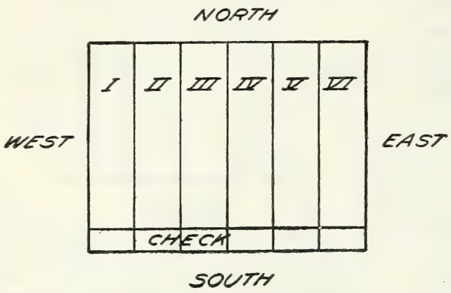


FIG. 8.—Diagram showing arrangement of experimental plats in the vineyard of Mr. J. M. Moorhead, Moorheadville, Pa., 1916. (Original.)

Two applications (1) with "set nozzles" and (2) with "trailers" (Plat IV) were partially effective, though not satisfactory. A single application with "trailers" when the berries were just touching (Plat III) was entirely unsatisfactory.

EXPERIMENT IN THE MOORHEAD VINEYARD, MOORHEADVILLE, PA., 1916.

An experimental plat of 48 rows, 8 rows per acre, was chosen in this vineyard. It was divided into 6 plats of 8 rows each. During the season of 1915 the infestation was heavy, 30 to 35 per cent of the berries being "wormy," with a tendency for heaviest infestation at the west side. Accordingly a transverse check of seven unsprayed vines at the end of each row was left. The arrangement of plats is shown by the diagram (fig. 8).

TABLE 16.—*Spray mixture used and methods and dates of application, Moorhead vineyard, Moorheadville, Pa., 1916.*

Plat No.	Date sprayed.	Arsenate of lead (powder.)	Bordeaux mixture.		Laundry soap.	Potash fish-oil soap.	Soft soap.	Water.	Method of application.
			Lime.	Copper sulphate.					
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Gallons.*	
I	July 8, 19	1½	3	3	1			50	"Trailers."
II	...do....	2½	3	3	1			50	Do.
III	July 8, 20	1½	3	3		2		50	Do.
IV	...do....	1½	3	3	1			50	"Set nozzles" first application; "trailers" second.
V	...do....	1½	3	3			1	50	"Trailers."
VI	July 20.	1½	3	3	1			50	Do.

TABLE 17.—*Percentage of infestation in experimental plats, Moorhead vineyard, Moorheadville, Pa., 1916.*

Plat No.	Number of vines.	Number of clusters.	Total berries.	First brood.		Second brood.	
				Infested berries.	Infestation.	Infested berries.	Infestation.
					Per cent.		*Per cent.*
I	20	850	29,750	243	0.81	1,752	5.88
Check I	6	253	9,108	406	4.45	3,812	41.85
II	20	675	23,625	154	.65	949	4.02
Check II	6	226	8,136	297	3.65	2,997	36.83
III	20	709	23,397	152	.64	806	3.15
Check III	6	195	7,410	340	4.57	2,848	38.43
IV	20	638	19,778	163	.82	1,307	6.61
Check IV	6	235	8,930	345	3.86	2,443	27.33
V	20	703	23,902	190	.79	4,605	19.60
Check V	6	224	8,064	174	2.15	2,741	33.99
VI	20	709	20,561	333	1.61	1,079	5.25
Check VI	6	154	4,312	86	1.99	1,010	23.39

The final counts showed satisfactory results in plats where two applications with "trailers" were made with poison and laundry or fish-oil soaps (Plats I, II, III). Fish-oil soap without resin as well as laundry soap was an effective adhesive, fish-oil soap having the advantage. A "soft soap" was also used (Plat V), but proved a very poor adhesive. Arsenate of lead at the rate of 2½ pounds (powder) to 50 gallons of liquid (Plat II) appeared to be little more effective at the increased strength than when used at the rate of 1½ pounds to 50 gallons (Plat I).

Plats where the first application was made with "set nozzles" (Plat IV) and where it was omitted altogether (Plat V) showed a fairly satisfactory reduction of infestation. It should be noted that the infestation in the checks in these two plats was not as heavy as that in the checks adjacent to Plats I, II, and III.

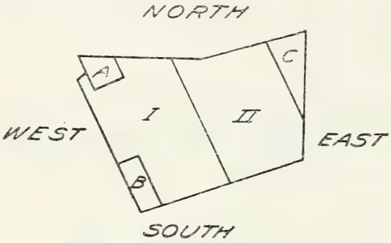


FIG. 9.—Diagram, showing the arrangement of experimental plats in the vineyard of Mr. M. D. Phillips, North East, Pa., 1916. The sprayed plats are marked with Roman numerals and the check plats with letters. (Original.)

EXPERIMENT IN THE PHILLIPS VINEYARD, NORTH EAST, PA., 1916.

This vineyard consisted of Niagara grapes, whereas in all other vineyards in which experimental spraying was done the grapes were Concords. It covered about two acres, irregular in shape, and was divided into two plats. To guard against natural irregularities of infestation unsprayed checks were left in each of the three corners. The arrangement of plats is shown in the diagram (fig. 9).

TABLE 18.—*Spray mixtures used and methods and dates of application, Phillips vineyard, North East, Pa., 1916.*

Plat No.	Dates sprayed.	Arsenate of lead (paste).	Bordeaux mixture.		Laundry soap.	Water.	Method of application.
			Lime.	Copper sulphate.			
		Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Gallons.*	
I	July 5 and 22	5	3	3	1	50	"Trailers."
II	July 5 and 22	3	3	3	1	50	Do.

TABLE 19.—*Percentage of infestation in experimental plats, Phillips vineyard, North East, Pa., 1916.*

Plat No.	Number of clusters.	Total berries.	First brood.		Second brood.	
			Infested berries.	Infestation.	Infested berries.	Infestation.
				Per cent.		*Per cent.*
I	400	15,200	436	2.87	479	3.15
II	400	16,000	107	.67	142	.89
Check A	200	7,200	423	5.88	5,135	71.32
Check B	200	7,600	1,186	15.61	6,114	80.45
Check C	200	8,000	289	3.11	4,034	50.43

Results in this vineyard showed that spraying will control the grape-berry moth fully as well in the very compact clusters of the Niagara grapes as in the less compact Concord. The test was thorough, as shown by the heavy infestation in the checks. Arsenate of lead used at the rate of 5 pounds (paste) to 50 gallons of liquid (Plat I) did not appear to have any advantage over 3 pounds to 50 gallons (Plat II).

The Spray Mixture.

ARSENATE OF LEAD, AMOUNT NECESSARY.

Arsenate of lead, either as paste or as powder, was the insecticide used in all field experiments. In all instances but one, when used at the rate of 3 pounds, paste, or 1½ pounds, powder, to 50 gallons of liquid, the amount was sufficient to reduce the grape-berry moth satisfactorily. During the seasons of 1915 and 1916 at least one plat was sprayed with poison at the above rate, and one other plat was sprayed under conditions as nearly the same as possible except that the amount of poison was increased to 5 pounds of paste or 2½ pounds of powder to 50 gallons of liquid. In all instances except the one referred to no distinct advantage was shown in favor of the higher amount, while in two of the vineyards the plats sprayed with the higher amount were actually the more heavily infested. The differences in results that did appear were usually slight and could be accounted for largely by variation of infestation. The comparative value of the two amounts of poison as it appeared in the different vineyards is summarized in Table 20.

Table 20.—*Relative efficiency of arsenate of lead at the rate of 3 pounds and 5 pounds (paste) to 50 gallons of liquid.*

Amount of arsenate of lead.	Treatments common to all plats.	Years tried.	Number of vineyards.	Number of plats.	Infested grape berries.					
					Best plat.	Adjacent check.	Poorest plat.	Adjacent check.	Average of all plats.	Average of all adjacent checks
					Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
3 pounds paste or 1½ pounds powder to 50 gallons of water.	Laundry soap, 1 pound, Bordeaux mixture (3-3 formula). 50 gallons applied twice with "trailers."	1915, 1916	7	7	0.89	50.43	8.43	75.16	4.12	50.03
The same as above. Poorest plat eliminated.		1915, 1916	6	6	......	......	......	......	3.41	49.17
5 pounds paste or 2½ pounds powder to 50 gallons of water.	....	1915, 1916	6	[1] 6	3.15	75.16	5.06	94.83	3.34	54.90

[1] Plat II, Miller and Carlburg vineyard, is not included in this average because the results were prejudiced by rain.

Table 20 indicates that as a rule there is practically no difference in effectiveness between the two amounts of poison. However, in the Southwick vineyard, 1916 (Plats I and II), the results in the plat sprayed with the higher amount appeared so much better in the final counts that the result could hardly be accounted for by variable infestation. Moreover, checks on either side showed that very little variation existed. In this vineyard at one end, although not throughout the vineyard, the checks showed an infestation very near to total, and probably enough moths had emerged to have totally infested a crop several times as heavy. Under such conditions of extremely heavy infestation the higher amount of poison was more effective. As previously stated in the discussion of results in the Southwick vineyard, the two amounts of poison were apparently equally effective when the first counts were made, but the higher amount withstood the weathering better and was more effective against the late second brood.

ADHESIVES.

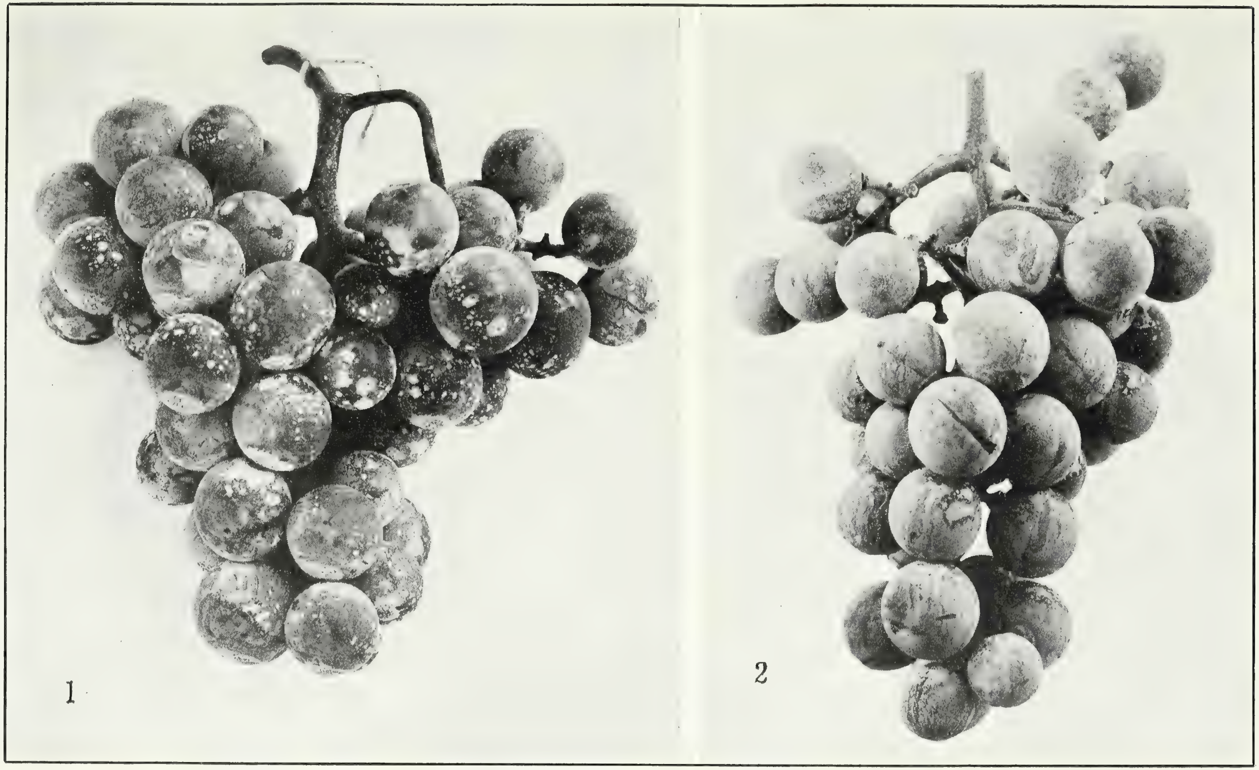
The necessity of adding adhesives to the spray mixture became apparent to the writer in the experiments in 1914. It was readily observed that the spray solutions from which an adhesive was absent did not adhere to the waxy skin of the grape berries, and this was undoubtedly one of the chief reasons for the failure to control the grape-berry moth during that season. The solutions to which soap was added appeared to adhere much better, but since this was used only in the last application a definite contrast in the final count was not shown. The counts in plats where soap had been added to the spray solution and applied with "trailers," however, when compared with counts in the nearest checks are consistently better than the others.

The effect of applying a spray mixture without adhesives was specifically demonstrated in 1915 by a comparison of the results in Plats V and IX in the Miller and Carlburg vineyard, pages 18–19.

TABLE 21.—*Relative effectiveness of spray mixtures with various adhesives and without adhesive.*

(Treatments common to all plats: Arsenate of lead, 3 pounds of paste or 1½ pounds of powder; Bordeaux mixture (3-3-50 formula) applied twice with "trailers.")

Kind of adhesive used.	Years tried.	Number of vineyards.	Number of plats.	Infested grape berries.					
				Best plat.	Adjacent check.	Poorest plat.	Adjacent check.	Average of all plats.	Average of all adjacent checks.
				Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Resin fish-oil soap	1916	1	1	......	......	......	......	2.14	55.53
Fish-oil soap (without resin).	1916 only.	2	2	......	......	......	......	1.97	31.29
Do.	1915, 1916	3	3	0.47	25.76	7.91	65.94	3.95	42.84
Laundry soap	1916 only.	4	4	......	......	......	......	4.14	61.79
Do.	1915, 1916	7	7	.89	50.43	8.43	75.16	4.12	50.03
Soft soap	1916	1	1	......	......	......	......	19.60	33.99
Flour paste	1915	1	1	......	......	......	......	18.89	28.80
No adhesive	1915	1	1	......	......	......	......	21.05	28.80



Spraying Against the Grape-Berry Moth.

Comparative spreading qualities in spray mixture of a laundry soap (fig. 1) and a resin fish-oil soap (fig. 2). (Original.)

From Table 21 it may be seen that fish-oil and laundry soaps used in the seasons of 1915 and 1916 were both effective as adhesives and that soft soap and flour paste were unsatisfactory. (See Pl. VI.) The advantage of one soap over another, as shown in the final counts, was usually so slight that it can not be considered significant.

At the time of application resin fish-oil soap appeared at best advantage. It was a better spreader than any of the others and consequently made the work faster and easier. It was used only in the Bartlett vineyard during the season of 1916. The potash fish-oil soap without resin also spread better than laundry soap. Potash fish-oil soap was used in 1915 in the Miller and Carlburg vineyard and in 1916 in the Moorhead and Bartlett vineyards.

The following analysis of the resin fish-oil soap used was made by the Bureau of Chemistry:

Water, 25.7 per cent.
Fatty and resin anhydrides, 68 per cent.
Sodium oxide, Na_2O, 4.3 per cent.
Undetermined, 2 per cent.

Laundry soap if carefully used is practically as effective and adhesive as the fish-oil soaps, but it has two distinct disadvantages, (1) it is a slower and a poorer spreader than fish-oil soaps, and (2) different makes of soap and even different lots of soap of the same make vary. In the experimental work each brand of soap was tried on a few vines with a hand sprayer before it was used in commercial experiments. If the vineyardist finds it necessary to rely on laundry soaps for an adhesive, this precaution would be advisable.

All of the laundry soaps that proved satisfactory were yellow resin soaps. Some of the so-called white soaps containing no resin were tried with a hand sprayer but lacked adhesive qualities and were not used in any field experiments.

Cutting the laundry soap and allowing it to dry out before using it in the spray mixture seemed to impair its sticking as well as its spreading qualities seriously.

A soft soap from a rendering factory also was tried, but gave negative results both as an adhesive and as a spreader. This was observed readily at the time of application, and the result is shown clearly in the final counts. (Moorhead vineyard, Plat V, 1916.)

Flour paste although a good spreader was an unsatisfactory adhesive, because it washed off with the first rain. (Miller and Carlburg vineyard, Plat VIII, 1915.)

When soap in the spray mixture is not dissolved thoroughly, clogging of the spray apparatus is likely to follow. Hot water was found necessary for quickest results. If the sprayer engine is water cooled, hot water from the water jacket can be used satisfactorily for this purpose.

Amount of adhesive necessary.—Resin fish-oil soap or laundry soap used at the rate of 1 pound to 50 gallons of liquid gave good results as a "sticker" and spreader. Potash fish-oil soap without resin was used at the rate of 2 pounds to 50 gallons of liquid.

NICOTINE SULPHATE.

Forty per cent nicotine sulphate was utilized in sprays every year in some of the vineyards against the grape leafhopper. This substance was used at the rate of 1 part to 1,600 parts of liquid in the last grape-berry moth spray. In 1915 it was used in both of the applications against the berry moth. In none of the plats on which it was used was there any indication that nicotine sulphate added to or detracted from the value of the spray mixture, so far as grape-berry moth control was concerned.

RELATION OF FUNGICIDES.

Bordeaux mixture had no insecticidal or repellent value, so far as the grape-berry moth was concerned. (Miller and Carlburg vineyard, Plat VII, 1915.) However, the addition of this fungicide seemed to be advantageous. Besides reducing the danger of burning by the arsenate of lead and soap combination it gave to the spray mixture physical qualities which lessened the tendency to collect on the lower surface of the berry.

The relation of neutral acetate of copper to arsenate of lead and soap was tried in an experiment on a small scale. It was thought that this nonstaining fungicide might be substituted for Bordeaux mixture if an August spray were adopted. One pound of neutral acetate of copper and 1 pound of soap to 50 gallons of water were mixed and applied to a few vines. The result was unsatisfactory. No injury to the foliage resulted, but the soap and neutral copper acetate in combination stained the grapes fully as objectionably as the soap and Bordeaux combination.

It had been demonstrated previously that the Burgundy mixture should not be used in combination with an arsenical, and it was not tried.

LIME.

When for any reason it was desired to omit Bordeaux mixture from the spray combination of arsenate of lead and soap, lime was added at the rate of 1 pound to 50 gallons of liquid.

INJURY DUE TO SPRAYING.

Combinations of arsenate of lead and soap with Bordeaux mixture or lime caused no injury to foliage in any of the three seasons of experimental work. If "nicotine sulphate 40 per cent" at the rate of 1 part to 1,600 parts of liquid was added to this solution it also was applied safely. However, the combination of arsenate of lead and soap alone produced slight burning of foliage in 1916. (Bartlett vineyard, Plat VII.)

No serious staining of fruit occurred except when the second-brood spray was applied in August in 1916. This was much reduced by using the arsenate of lead and soap with lime instead of with Bordeaux mixture.

METHOD OF APPLICATION.

The first season's experiments clearly demonstrated the difficulty in covering grape clusters by the "set-nozzles" applications. This was particularly inadequate at the last application, at which time the foliage is very heavy, and pressure up to 250 pounds was not effective. The use of "trailers" on a few plats for the last application suggested the complete change of method which followed the next season.

A specific demonstration of the inadvisability of depending on "set nozzles" as a means of applying spray was shown in 1915 by the contrast between Plats I and X in the Miller and Carlburg vineyard.

The necessity of using "trailers" was so satisfactorily established in the first two seasons that during 1916 "set nozzles" were not used in both applications in any plats. However, in the Moorhead vineyard, Plat IV, and in the Southwick vineyard, Plat IV, "set nozzles" were tried for the first application. In the former, at the time of the first application, the results were reasonably satisfactory, although not the best. In the latter vineyard the foliage was very heavy when "set nozzles" were used, and the failure to cover the clusters with spray was obvious. The reduction of infestation that resulted should be credited largely to the last application, which was made with "trailers."

The relative efficiency of "set nozzle" and "trailer" methods of application and a combination of these methods is shown in Table 22.

TABLE 22.—*Relative efficiency of "trailer" and "set nozzle" methods of application.*

(Treatments common to all plats: Arsenate of lead, 3 pounds paste or 1½ pounds powder; laundry soap, 1 pound; Bordeaux mixture (3-3-50) applied after falling of blossoms and when grape berries were just touching.)

Method of application.	Years tried.	Number of vineyards.	Number of plats.	Infested grape berries.					
				Best plat.	Adjacent check.	Poorest plat.	Adjacent check.	Average of all plats.	Average of all checks.
				Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
"Trailers," 2 applications	1915, 1916	7	7	0.89	50.43	8.43	75.16	4.12	50.03
"Set nozzles," 1 application; "trailers," 1 application	1916	2	2	6.61	38.43	19.13	65.65	12.87	52.04
"Set nozzles," 2 applications	1915	1	1	20.41	28.80	20.41	28.80	20.41	28.80

Usually when "trailer" applications were made the sprayer was driven only in every other alley between the grape rows, each rodman spraying both sides of his row on the same trip.

During the season of 1915, in the Moorhead vineyard, Plats II and IV, the sprayer was driven in every alley, each rodman spraying only one side of a row on each trip. While it was easier to cover the foliage by this method, it was slower and it showed no distinct advantage over the usual method, in controlling the berry moth. It was given no further trial. Which of the two methods is best is probably a matter of individual preference.

Careful work was an absolute necessity for successful "trailer" applications. While the responsibility rested chiefly with the rodmen, unless the driver was careful about gathering up the hose and at the same time allowing the rodmen time to finish spraying each vine the work was handicapped greatly. It was necessary also that the rodmen should make an effort to cover each cluster or the advantage of "trailers" over the strictly mechanical method was lost.

Time and Number of Applications.

The most satisfactory spray schedule was as follows: The first application to be made immediately after the falling of the bloom; and the second application about two weeks later, at the time when the berries are just touching. This proved effective both in 1915 and in 1916, and was the schedule used in the majority of plats.

A single application at the time the berries were just touching reduced the infestation greatly, but hardly offered satisfactory results. It was tried only in the season of 1916. This spray is intended for late first-brood larvæ, and enough of the poison will remain on the berries, at the time of the hatching of eggs of the second brood, greatly to reduce this brood as well. The effect of this spray against the second brood is shown by referring to the counts in Bartlett (lower) vineyard, Plat I, in comparison with the adjacent Check Plat A. Plat I was naturally more heavily infested than was Check Plat A, as the first-brood count showed that it had about 50 per cent more infested berries than did "A." On the other hand the final count showed the percentage of infestation in Check Plat A to be three times as heavy as that in Plat I. Similar final results are shown in Southwick vineyard, Plat IV. The results in the Moorhead vineyard, Plat VI, would indicate that in case of light infestation this one application might control the berry moth satisfactorily.

In 1916 a single application, made on August 12 and aimed directly against the second brood, also reduced the infestation considerably, as shown in Bartlett vineyard Plat II, although the counts did not appear as favorable as the single earlier application previously mentioned as being made when the berries were just touching. This was probably due to the fact that the absence of the early application permitted all of the first brood to enter the berries and heavier oviposition later resulted. Furthermore, dependence upon an application as late as August 12, alone, is open to objection even if the second-brood control was very good, because infestation by the first brood will usually seriously thin out the clusters, and too, the spray remains longer on the berries, leaving them seriously stained at harvest time. This application is harder to make than is the earlier one because the foliage at the later date is much heavier. The value of the application is largely that of an emergency measure, at a time when the first brood has not been controlled.

A three-spray schedule was tried in Plat IV of the Bartlett (lower) vineyard. The infestation was less than in Plats III and V, which had been sprayed twice. However, in this instance the difference was not of commercial importance and would not pay for the extra application, and the fruit was stained so badly by the last application as to reduce materially its value on the basket market. This third application could be of value in this region only under extraordinary conditions, when faulty work or lack of spray materials and labor or unfavorable weather had prevented the control of the first brood.

A comparison of the results of different spray schedules is given in Table 23. The average infestation of plats where two applications were made was distinctly heavier than was the infestation in the one plat where three applications were made. It should be noted, however, that where the plats sprayed two and three times were adjacent in the same vineyard, the difference in infestation was very slight.

It also shows that the single application may produce fair control if the infestation is light, but that on the whole dependence on a single application is unsatisfactory.

A spray application before the grapes blossomed, followed by the usual two applications after the falling of the blossoms, was tried in one plat in each vineyard in 1914. No beneficial results of this spray could be noted when the final counts were made. The importance of this spray was brought into question soon after its application, for very few larvæ were found in the clusters before the next was applied. Even had they been numerous at that time, the "preblossom spray" could hardly have been effective, as practically all of the poison that did adhere to the clusters when applied fell off a few days later with the flower caps.

This early spray was applied again in 1915 in all three vineyards, but since practically no larvæ were found until the blossoms fell, these plats were discarded.

TABLE 23.—*Relative efficiency of different times and numbers of applications.*

Time and number of applications.	Treatments common to all plats.	Years tried.	Number of vineyards.	Number of plats.	Infested grape berries.					
					Best plat.	Adjacent check.	Poorest plat.	Adjacent check.	Average of all plats.	Average of all adjacent checks.
					P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Two applications after blossoms have fallen and when grape berries are touching.	Arsenate of lead, 3 pounds paste or 1½ pounds powder; laundry soap, 1 pound; Bordeaux mixture (3-3-50), applied with "trailers."	1915, 1916	7	7	0.89	50.43	8.43	75.16	4.12	50.03
Two applications, same as above, including only plat adjacent to that sprayed 3 times.	.....do..........	1916	1	1	1.57	79.72	1.57	79.72	1.57	79.72
Three applications, 2 same as above; third 5 weeks after first.	.....do..........	1916	1	1	.68	67.52	.68	67.52	.68	67.52
One application when grape berries are touching.	.....do..........	1916		3	5.25	23.39	33.95	75.16	18.71	51.29
One application 5 weeks after falling of blossoms.	(1)..............	1916	1	1	19.97	55.53	19.97	55.53	19.97	55.53

[1] Same as above, except arsenate of lead, 2½ pounds, and resin fish-oil soap instead of laundry soap.

FACTORS DETERMINING THE TIME AND NUMBER OF APPLICATIONS.

The time and number of applications are determined not only by the seasonal history and habits of the grape-berry moth, but also by the development of the grape itself. Fortunately the times for spraying, most favorable in relation to the pest and also in relation to the crop, are nearly coincident. It is probable, therefore, that the vineyardist will find it most convenient to time his operations entirely by the development of the fruit.

The first spraying probably destroys the largest number of first-brood larvæ, for it is applied just before they begin hatching in numbers. Besides these, it also destroys some larvæ which hatch before the blossoms fall and are feeding in the cluster, but have not entered a grape berry. Following this application the grapes grow very rapidly and the larger part of the berry surface does not long remain covered. But as at this time the majority of the larvæ enter the berry at the stem end, where the spray always collects, comparatively few escape.

The second application is made after first-brood hatching begins to decline, but it is effective against the second brood also. As soon as the berries begin to touch, the majority of larvæ begin entering at the points of contact instead of at the stem ends. Spray which is applied at this time is especially apt to collect at these places again, at which point it may be most effective later. It also covers the berry, and since there is comparatively little growth following this, it remains over the larger part of the surface until it is weathered off, or for about two months. Thus it remains effective during the period when the greater part of the second-brood larvæ hatch. As shown by the single-spray applications in 1916, this second spraying is practically as effective against the second-brood larvæ as is one applied three weeks later, just as they are beginning to hatch.

Larvæ which succeed in entering the first berry may be poisoned upon moving to a second. Larger larvæ seldom consume enough poison to prevent their entering the grape berry, but may be found dead in the berry a day or two later, whereas those that have reached the fourth stage are seldom susceptible to poison in the amounts in which it is to be found, after weathering, on sprayed grapes.

If this schedule is followed closely, the places on the grape berry at which the majority of the larvæ would normally enter should be well covered with poison, and the surface of the berry as a whole will be covered for a longer time than by two sprayings applied at any other time. If the first application were made earlier, before the falling of the grape blossoms, most of the poison would be lost with the shedding of the floral parts, and the application would be comparatively ineffective. If the second application were made earlier, while the berries were still growing rapidly, it could not cover the surface of the berries permanently nor could it collect at the points where the berries would touch, and while it might destroy more of the first brood, it would be almost entirely ineffective against the second. Hence no variation in the time of these two applications is advisable.

RELATION OF DIFFERENT GRAPEVINE TRAINING SYSTEMS TO SPRAYING.

The system of pruning and training a vineyard must be largely determined by horticultural considerations. Nevertheless the different systems greatly affect the facility with which the grapes may be sprayed and in other ways are related directly to the control of insect pests. To determine the relation to grape-berry moth control of five of the more important systems, a small block in Mr. A. P. Bartlett's vineyard was used in 1916. In all of the other spraying experiments the vines had been trained according to the Chautauqua system. This block was trained by the owner especially for this experiment according to the Four-cane Kniffin, Munson, Umbrella, High-renewal, and Chautauqua systems.

As there may be many who are not familiar with all of these vine-training systems the following brief descriptions have been compiled from the papers of Husmann (15) and Gladwin (14).

Chautauqua system.—This is the system used most frequently in the Erie-Chautauqua grape belt. The stem reaches only to the lowest wire from which permanent arms to suppport the canes are carried right and left along the lower wire. The canes, usually about 4, are carried upward and tied to the upper wire or wires.

High-renewal system.—The head of the vine reaches only the lowest wire of the trellis, and the canes are tied right and left along this wire. The fruiting shoots growing from these canes are trained upright and fastened to the wires overhead.

Four-cane Kniffin system.—The stem is carried directly to the top wire of a two-wire trellis. Two canes about the level of each wire are tied right and left along each wire.

Umbrella system.—This system differs chiefly from the Kniffin in that two canes are left instead of four. They are started at the upper wire and the extremities are tied down to the lower wire.

Four-cane Munson system.—This system differs from the others mentioned in that it requires an overhead trellis. Across the top of each post a crossbar 20 inches long is fastened and outer wires are fastened at the ends of these crossbars, while an inner wire is fastened to the post about 6 inches lower down. A single stem is carried to the inner wire and four canes are left, one carried in each direction along each wire.

Two regular first-brood applications with ''trailers'' were made. Vines trained according to any of these systems could be sprayed thoroughly and the difference in final counts is not significant, but the ease with which the applications were made is of considerable importance.

The Kniffin and Munson systems were much the easier to spray. The time required was about 15 per cent less than that required for the Chautauqua system. These systems had the advantage of having no upright shoots or canes to interfere with a free action of the spray rod. The fruit, although well protected by leaves above at the time of spraying, was well exposed below. The bunches hung, in the Kniffin system in two layers, one below each wire, and in the Munson system just below the trellis, and consequently were easy to find. The Munson system had the disadvantage of producing a dense shade, and consequently favoring grape-berry moth infestation.

In contrast to this, the Chautauqua system presented the disadvantage of upright canes, which interfered with free action of the spray rod and with fruit arising from anywhere up and down these canes. The clusters were well protected by leaves and often isolated, and greater care was necessary in finding them and covering them with spray.

The umbrella system with the canes bent down from the upper wire to the lower presented a difficulty in spraying similar to that of the Chautauqua system, although it seemed slightly easier to spray. The high-renewal system was much more difficult to spray owing to the tendency of the rods to catch in the numerous upright shoots.

Summary of Important Factors in Spraying Practice.

The most important factors in spray practice to control the grape-berry moth, shown by the final counts in 28 of the 49 experimental plats of three years, are summarized briefly in Table 24. Factors of minor importance such as a complete comparison of adhesives and value of nicotine sulphate are omitted. In addition, the plats in the experiment in the Phillips vineyard, 1914, because of the erratic infestation, and the plats in the Miller and Carlburg vineyard, 1915, which were affected by rain, are excluded.

Table 24.—*Relative efficiency of spraying measures tried.*

Spray mixture, method of application, and spray schedule followed.	Years tried.	Number of sprayed plats.	Infested fruit.	
			Average in sprayed plats.	Average in adjacent unsprayed checks.
			Per cent.	*Per cent.*
I. Arsenate of lead, paste, 3 pounds, or powder, 1½ pounds; laundry soap, 1 pound; Bordeaux mixture, 3-3-50. Applied with "trailers" immediately after blossoms had fallen and again when grape berries were just touching (or about 2 weeks later)	1915, 1916	7	4.12	50.03
II. Same as I except arsenate of lead omitted	1915	1	33.31	28.80
III. Same as I except adhesive omitted	1915	1	21.05	28.80
IV. Same as I except Bordeaux mixture omitted	1916	1	4.01	88.74
V. Same as I except arsenate of lead increased to 5 pounds (paste) or 2½ pounds (powder)	1915, 1916	6	3.34	54.90
VI. Same as I except resin fish-oil soap used instead of laundry soap, 1 pound	1916	1	2.14	55.53
VII. Same as I except fish-oil soap (without resin) used instead of laundry soap, 2 pounds	1915, 1916	3	3.95	42.84
VIII. Same as I with addition of a third application 5 weeks after first	1916	1	.68	67.52
IX. Same as I (including only the plat adjacent to VI)	1916	1	1.57	79.72
X. Same as I except first application omitted	1916	3	18.71	51.29
XI. Same as I except "set nozzles" used in first application instead of "trailers"	1916	2	12.87	52.04
XII. Same as I except "set nozzles" used in both applications instead of "trailers"	1915	1	20.41	28.80
XIII. Same as I except adhesive omitted and "set nozzles" used in both applications instead of "trailers"	1914	1	26.70	31.80

This table shows that both arsenate of lead and soap are essential factors in the spray mixture, while Bordeaux mixture is of little importance. An increase in the amount of arsenate of lead is usually of little value, and variation among the three kinds of soap used is not an essential consideration. Two applications effect a practically satisfactory control so that the advantage of a third application is insignificant. The omission of the first application, or making it with "set nozzles" instead of with "trailers," furnishes on the average only a partially satisfactory measure, while complete substitution of "set nozzles" for "trailers" is entirely unsatisfactory.

SPRAY COMBINATIONS

A combination of sprays may be made, to control, besides the berry moth, practically all other important enemies of the grape in this region—the grape rootworm, the grape leafhopper, and the powdery mildew. These spraying recommendations for the control of enemies of the grape other than the grape-berry moth are based on recommendations of other investigators,[1] and were employed incidentally in connection with the berry-moth experiments.

The time of the first spray application for berry moth, just after the grape blossoms fall, during the seasons of 1914, 1915, and 1916, has been from 2 to 4 days before the appearance of the rootworm beetles. Without change of time or mixture this application is effective against the rootworm also. If this application is intended as rootworm control also, care should be taken to cover the upper surface of the foliage, for unless extra attention is given to this it is apt to be done less effectively with "trailers" than with "set nozzles." In exceptional instances an extra application for rootworm control may be necessary. This combination must not be attempted if it is desired to add molasses or sugar to the rootworm spray, as mixtures containing sugar are very soluble and wash off the vines readily. Furthermore, a combination of sugar with Bordeaux mixture is apt to burn foliage.

The second berry-moth spray, applied when the berries are just touching, may be made effective also against the grape leafhopper by the addition of nicotine sulphate (40 per cent) at the rate of 1-1,600 ($\frac{1}{4}$ pint to 50 gallons.)

By the addition of Bordeaux mixture in these two applications, powdery mildew also can be controlled. These two applications of Bordeaux will be useful against black rot and downy mildew also, where these occur, although an additional earlier spray will be necessary for the control of these diseases.

COST.

The cost of spraying material and labor required to control the grape-berry moth, if applied to control the berry moth alone, is about $5 per acre. In computing this cost it is assumed that an average of 6 acres are sprayed per day and that 150 gallons of liquid are applied per acre. This average may not be maintained if the water supply is inconveniently situated and the spraying machinery is not kept in condition, but delays due to these sources are not normally necessary. These figures do not include interest on money invested in the spraying machine, depreciation, breakage, or incidental costs of operation, such as gasoline and oil, since these vary greatly. The details of cost for a single application are as follows:

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[1] See Quaintance and Shear (12), Johnson and Hammar (13), Johnson (17), and Hartzell (18).

Materials for 150 gallons of spray mixture:	
Arsenate of lead (paste), 9 pounds, 8 cents per pound	$0. 72
Lime, 3 pounds, ⅓ cent per pound	. 01
Resin fish-oil soap, 3 pounds, 6¼ cents per pound	. 19
Labor, 3 men, ⅙ day at $2 per day	1. 00
1 team, ⅙ day, at $3 per day	. 50
	2. 42

For the two applications the cost would be $4.84 per acre.

The entire cost, however, need not be charged to berry-moth control if a combination spray is used. These two spray applications are necessary in the majority of vineyards to secure the greatest possible profits, even if the berry moth is not present. In a vineyard where control measures are already employed against the rootworm, leafhopper, and powdery mildew, the additional cost per acre in controlling the berry moth would be as follows:

Extra cost of labor for using "trailers" instead of "set nozzles" in the first application.		
Labor cost with "trailers" (see above)	$1. 50	
Labor cost with "set nozzles," 1 man and team ⅛ day at $5 per day	. 675	
		$0. 825
Arsenate of lead (paste), 9 pounds for second application, at 8 cents per pound		. 72
Soap, 6 pounds (2 applications), at 6¼ cents per pounds		. 375
Total		1. 920

Thus, if spraying for rootworm, leafhopper, and mildew is properly done the extra cost of spraying for the grape-berry moth is only $1.92 per acre.

SUMMARY AND RECOMMENDATIONS.

The grape-berry moth can be controlled by spraying. Other methods will reduce berry-moth infestation, and some of them can be employed profitably to increase the efficiency of spraying, but none offers a dependable control in commercial vineyards.

Gathering and destroying grape leaves in the fall is of little use in berry-moth control.

Bagging grape clusters immediately after the setting of the fruit will exclude the berry moth and prevent infestation, but the expense is prohibitive in commercial vineyards in this region and may be used advantageously only in garden vineyards. Hand picking of grape berries infested by first-brood larvæ, if done by competent labor, will reduce berry-moth infestation, but except in extraordinary cases will not control it. When spraying can be employed these measures are unnecessary.

A number of other measures reduce infestation and generally may be employed as a part of vineyard practice without additional expense. When commercial vineyards are infested, the worst areas should be harvested as early as possible and the "trimmings" removed, to secure the largest weight for the crop and to remove as many larvæ as possible from the vineyard. Clearing away brush in the neighborhood of a vineyard will destroy the protection for hibernating pupæ with an ultimate reduction in infestation. When it is in keeping with cultural practice, pupæ hibernating under the vines should be covered with earth in the spring by plowing, and this covering should remain until the period of blossoming of the grapes, when it should be removed with a horse hoe. This plowing should not be allowed to interfere with spraying.

These practices, it must be remembered, while reducing infestation, will not control it, and they should not be expected in any way to take the place of spraying.

The following spraying practice has been found most satisfactory:

The spray mixture—		
Arsenate of lead—		
Paste	pounds	3
Or powder	do	1½
Resin fish-oil soap	do	1
Bordeaux mixture—		
Copper sulphate	do	3
Lime	do	3
Water	gallons	50

Method of application, with "trailers":

Spray schedule—

First application, immediately after falling of grape blossoms.

Second application, when grape berries are just touching (or about two weeks later).

Under some conditions it may be desirable to modify the spraying practice outlined above.

In case of extremely heavy infestation the amount of arsenate of lead should be increased to 5 pounds (paste) or 2½ pounds (powder), at least in the last application.

If resin fish-oil soap is not available a laundry soap containing resin may be substituted in its place. Laundry soaps, however, vary greatly in their sticking and spreading qualities, and great care should be used in selecting those best suited to this purpose. Whatever soap is used, care must be taken to have it thoroughly dissolved before adding it to the spray mixture to prevent clogging of the spraying machinery.

The use of Bordeaux mixture, while not having a direct effect upon the berry moth, is recommended, to prevent burning of the grape foliage by the combination of arsenate of lead and soap. Lime at the rate of 1 pound to 50 gallons may be substituted instead. Since it is very rarely that the fungicidal spray can be omitted with profit, the use of Bordeaux mixture is preferred.

This spraying combination should control any infestation of the grape-berry moth, such as the writer has observed during three seasons in the Erie-Chautauqua grape belt, and has been applied successfully under very unfavorable weather conditions. If, however, through faulty spray materials or work, or adverse weather at the time of spraying, these applications fail to control the first-brood larvæ, they may be supplemented by a third application five or six weeks after the first, with the understanding that the fruit is likely to show heavy staining at time of harvest. This staining may be reduced by omitting Bordeaux mixture from the solution applied and using instead 1 pound of lime in 50 gallons of water.

In case the foliage is very light at the time of the first application, expenses may be reduced somewhat by using "set nozzles" at this time and using "trailers" only for the second application. Single spray applications, either at the time the grape berries are just touching or about three weeks later, will reduce the infestation and in some instances control it. Such measures to reduce expenses of spraying, however, are dangerously likely to fail in reducing the infestation satisfactorily, and should be adopted with great caution.

Spraying operations will be facilitated greatly by training the vines so that the clusters may be reached most quickly and covered with spray. In a limited experiment the Kniffin system seemed most satisfactory for this purpose.

The applications required for the control of the grape-berry moth are so timed that they may be combined with applications to control the grape rootworm, grape leafhopper, and powdery mildew, and some of the applications for downy mildew and black rot also may be combined with them. Nothing need be added to the spray solution for rootworm control; nicotine sulphate (40 per cent) at the rate of 1 to 1,600 should be added to the second application for leafhopper control; and Bordeaux mixture should be used in both applications for fungous diseases.

The cost of spraying to control the grape-berry moth need not exceed $5 per acre. If the applications are made to control other pests as well, the charge against the berry-moth control should be considerably less.

It should be borne in mind that unless the proper spray mixture is applied at the right time and the clusters are thoroughly covered, the work is of little value.

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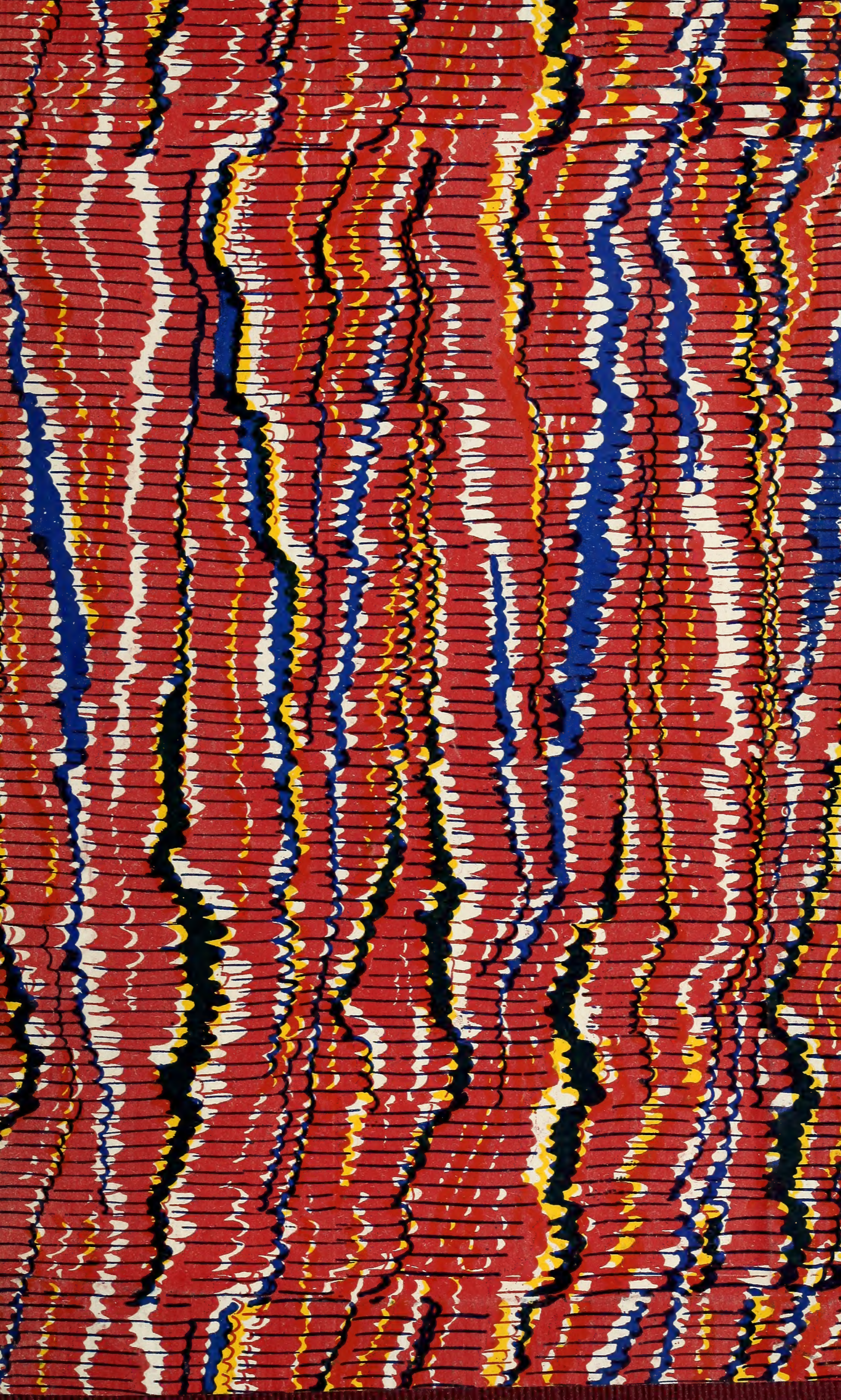

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